



EPIDEMIOLOGICAL STUDY AND COMMENTS ON TWO HIGHLY CONTAGIOUS DISEASES IN
AFRICA

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A Thesis Submitted to the of Computational Science program, Addis Ababa UNIVERSITY

IN PARTIAL FULLFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF
COMPUTATIONAL SCIENCE

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September 2020

Declaration

I, Addis Gebremedhin Kifle, hereby declare that, this thesis represents my own work and has not been submitted previously for examination towards any degree or diploma qualification at any other University.

Date

Signed

**EPIDEMIOLOGICAL STUDY AND COMMENTS ON TWO HIGHLY CONTAGIOUS DISEASES
IN AFRICA**

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Acknowledgment

I want to thank my creator, God almighty the father the Son and Holy Spirit for His endless love, for He has given me divine wisdom, protection and good health, God has given me opportunity throughout the period of my studies here in Addis Ababa university. I am also very much thankful to my courageous adviser who is never get tired of teaching to Professor OKEY OSELOKA ONYEJEKWE who encouraged me made my Master's degree up to Thesis level possible. In addition when I get difficulties of solving the problem of ODE he was there to explain the problem in different method of solving equations and by giving his materials and his support in taking time to advise me out of his tight schedules it is a privilege and make me feel proud for I being his student and for he has given me opportunities to be my adviser, once again I would like to say thank you Prof. may God give you full health and I wish you long life.

Also I would like to thank my friends, especially my class mate Engineer Nahom Alemseged Worku who assisted me a lot on my Thesis paper and encouraged me for my dream to come to possible and for the courage he gave me to accomplish my studies. May God help him in any situation that he endeavors in his studies I wish him success, achievement and accomplishment in his studies may God abundantly bless him.

Furthermore I would like to thank my family especially my wife for the courage that she has given me throughout my studies in all this period which I went through difficult time and happy time, I would like to say once again thank you and I wish you a better life with me through my life time. God bless you and the entire family.

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Abstract

Epidemiological studies and comment on two highly contagious disease Ebola and Coronavirus Outbreak from the bases of Computational Science program and Epidemiological models considering Susceptible, Infected, Recovered, Vaccine, Quarantine and Death etc. trying to illustrate the activity of Ebola and Coronavirus disease Outbreak in many ways like figurative ways in different compartement which illustrate detail from Supceptible to Infected from infected to Recover stage and from infected to quarantine stage or death etc. And from that observation asesement method computitional by which I learnt in Computational science departement by appling mathimatical model using Ordinary differential equation,these equations model the dynamics of the transitions from the mathimatical model SIR,SIRD,SIRV,SIQR, and Algorithm, using Matlab codeing and plot. I learnt and recogized how the disease moves and behaves from one Compartement to another compartement and how it incline and decline of each activity on the figuer. By certain mathimatical model, by using algorithim by setting Matlab code and by plotting graphs through Matlab program, I tried to show how the cases of the Virus it behaves from one stage to another stage how it increases,decrease and recover from supceptable stage to infected stage and recoverd or quarntine (death) stage.

The progress between these sections could be presented as formal mathimatical terms to make quantitative predictions and interpolation,we can translate them into formal mathematical terms. This paper illustrate the stage of the diseases, the level of the diseases and describes by using mathematical models by using collective data in Table, Tabular form by ploting graphs to illustrates these models together with the kinds of mathimatical model analyses that have proved which is useful to epidemiologists. West Africa Ebola disease outbreaks from 2013-2019 and Coronavirus 2019-2020 has brought to light the significance of epidemic modeling and pandemic modeling at a time considered when many serious illnesses are no longer a threat to Public Health. Between regions and continents Countries the increasing connectivity makes it to understand the mechanisms that drive the spread of new acute illnesses and our ability to control them at the source more important now than ever before.

In general Epidemiology of the Ebola and Coronavirus in particular it is a disease, poorly understood, and capable of causing threat to Public Health and corona virus disease is considered analyzed statistically and model using the SIR,SIRD,SIRV, and SIQR model. Differential equation formulated the non-linear systems of solving numerically using MS-Excel and Mat-lab program over time period of 120 days. For simplicity, Democratic Republic of Congo, Liberia, Guinea West African Countries that was hit severely by EVD in 2014 was used for this study. As stated earlier, modeling infectious disease dynamics demands that we

investigate whether the disease spread could accomplish an epidemic level or pandemic it could be wiped out. The Ebola and covid-19 Virus is spread largely through contacts between an infected person and a non-infected person. Infected people cannot be entirely separated or quarantined from the rest of the large population in the case of Ebola but in the case of Covid-19 entirely we separate and isolate the infected person from the people. In the case of Ebola the separation can only be done when an infected person visits a health center but in the case of Corona virus we trace and isolate or separate them from the beginning we identify the person who is positive.

Keywords: Epidemiological models, COVID-19, Ebola, Herd immunity, SIR model, Euler's method, Equilibrium, Endemic Equilibrium, disease free equilibrium, Non pharmaceutical Interventions, Infection Rate, Recovery rate.

Abbreviation:- ECDC, ODE, SIR, SIRD, SIRV, SIRQ.

ECDC: European for Control Diseases Center

ODE : Ordinary differential Equation

SIR : Susceptible, Infected, Recover

SIRD: Susceptible, Infected, Recover, Death

SIRV: Susceptible, Infected, Recover, Vaccine

SIRQ: Susceptible, Infected, Recover, Quarantine

β : represent a parameter for Beta.

γ : represented by Gamma

Chapter 1 Introduction

Ebola is a disease mostly affects people, monkeys, gorillas, and chimpanzees and disease with infrequent outbreaks which happen mainly in African. In 1976 Ebola virus was first shown near Ebola River, what is now Congo and with a set of viruses within the types Ebola virus is caused by an infection. In their day to day life, leading to outbreak in several African countries since then, the disease has been infecting people. Scientists do not know where Ebola disease originates from, it is uncertain. Sick animals carrying the virus can spread it to other animals, like apes, monkeys, duikers and humans [1]. West African countries On 23 March 2014 since then cases have been described in 5 additional and timeline links to key events WHO African Regional Office described an occurrence of Ebola disease this collaborating in Guinea, stories and further reading from 23 March 2014 - 23 July 2015 [2]. World Health Organization in total giving, there were 318 cases of Ebola in 1976 and there were 11,310 deaths out of closely 29,000 cases 280 deaths in an outburst that lasted less than 11 weeks. In the recent West Africa outbreak and the epidemic lasted more than two years almost 10 times as long as in 1976. 318 people were affected in 280 deaths in 1976 incidence and limited to one village. Since the existing epidemic initiated in early 2014, more than 7,400 people have been infected about 3,400 people have died of Ebola [3]. Despite obstacles, in 1976 control and were delayed because of late acknowledgment research was a priority and newly an worldwide commission working pleasantly in laboratories and with local societies was essential for fast success and because authorities were overwhelmed by many patients and poor community involvement[4]. Inquiry teams were organized on October 30th the WHO Global Commission was formed on October 18th. November 5, 1976 the last case of EBO-Z died on A parenteral injection of chloroquine understanding of the recent West African outbreak he received (an anti-malaria drug) from Yambuku Mission Hospital (YMH). Disposable needles YMH did not use or sterilize the needles. primary mode of administering nearly all medicines Ebola-Zaire first Ebola outbreak in Sudan and killed 280 of the 318 people it infected EBO-Z surfaced shortly after and parenteral injection was quickly disseminated into the surrounding villages serviced by YMH [5]. A person who gets sick with coronavirus disease get sick will experience respiratory illness and recover without serious treatment. A newly discovered caused by (COVID-19) and Cardiovascular disease, diabetes, chronic respiratory disease, older people and those with underlying medical problems like and cancer are more likely to develop serious illness and to minimize the transmission and the best way to avoid from the disease is to be well informed about the virus. The disease will cause how it spreads by washing your hands or using an alcohol based clean often protects yourself and others from infection and not touching your face. Coronavirus disease it affects the respiratory system and it accelerates others diseases caused by coronavirus disease. According to the WHO, coronavirus is caused by infection with a virus of others to the family and

the disease, which the World Health Organization declared an outbreak on 11th March 2020. Coronavirus (Covid-19) disease particularly is contagious disease, and poorly understood, and capable of causing a large-scale threat to the world Public Health and now days a threat to the whole world. The disease will spread close personal contact and by breathing of a person in the distance of two meter. This outbreak was the first recognition of the virus. Since then, there have been many outbreaks with the latest in China (Wuhan), Asia, Europe, America, Africa and now days the entire world. Covid-19 Virus which began in Wuhan China and killed thousands of thousand even million people since the virus out break from Wuhan [6].

1.1 Background

In 1976 after simultaneous Ebola virus was identified and highly deadly outbreaks of hemorrhagic fever occurred in northern Zaire now the Democratic Republic of Congo (DRC) and southern Sudan, each virus caused by a different strain. Ebola-Zaire case 90% of these s, and 50% of these Ebola-Sudan cases, resulted in death. In Africa Periodic occurrences of Ebola afterwards arose, mainly within the Congo and Nile basins. For the location where there are three additional tensions of Ebola virus, also named they were first quarantined, have been identified, among a single types of macaques from one contextual facility although first documented among Ebola disease laboratory monkeys in the United States, actually originated in the Philippines. Virus that seemingly does not reason simple disease in humans Ebola and it kills monkeys, however, and it has been recently improved from illness swine in Southeast Asia [7].

The onset of Ebola is characterized by fever, severe headaches, bloody diarrhea, vomiting, stomach pain, muscle pain, unexplained bleeding or bruising, weakness and lack of appetite what prevent humans and Primates from being the natural host is that, it destroys those infected with the virus so quickly. Virus indicates the genetic analysis, it is closely related (97% identical) to variants of Ebola virus (species Zaire Ebola virus) identified earlier in the Democratic Republic of the Congo and Gabon. Recently the 2014 Ebola outbreak is one of the largest Ebola outbreaks in history and the first in West Africa. Ebola virus Disease (EVD) can only be spread to others after symptoms begin. The incubation period of Ebola is 2-21 days after exposure to Ebola virus, although the infections period is most commonly 4-10 days [8].

Ebola is transmitted through primary contact with body fluids from the infected. It can also be transmitted through secondary contact by family members caring for the infected and also where infection control mechanisms are not in practice such as wearing gloves or washing of hands etc. Ebola is frequently misdiagnosed and Ebola can be difficult, because as typhoid and malaria; currently there is no treatment of Ebola. In partnership with the Ministries of health in Gunnies, Sierra Leone, Liberia, and Nigeria reported 2615 suspected and confirmed cases of EVD, including 1528 laboratory-confirmed cases and 1427 deaths with the following breakdown. In Guinea, 607 cases of EVD, including 443 laboratory confirmed cases, and 624 deaths; Nigeria 16 suspected cases of EVD, including 269 laboratory-confirmed cases, and 624 deaths; Nigeria 16 suspected cases of EVD, including 12 laboratory-confirmed cases and 5 death control and prevention (CDC) is working with other U.S government agencies the WHO and other domestic and international partners Ebola outbreak in West Africa was international response. In 1892 Corona virus began infectious virus was isolated, coronavirus respiratory syndrome by severe acute respiratory syndrome corona virus and Middle East respiratory syndrome corona virus in 2012 and about 21,000 deaths out of over

470,000 cases with about 82,000 reported by China and a total of over 380,000 confirmed from 194 countries up to 25th March 2020. The source of Covid-19 virus is from China Wuhan. The coronavirus (Covid-19) disease was first recognized in 11th March 2020 China Wuhan. Since then, various tensions of the virus have emerged and outbreaks have occurred. A fact is interesting with the Covid-19 virus is that it is a unique member of family that has no exact origin, locations and natural habitat, which remains unknown. However, based on the nature of similar viruses, researchers believe that the virus is unclear. This means the virus is animal-borne i.e. a virus that normally exists in outbreak from China Wuhan laboratory but that can infect humans health mainly it affects the respiratory part of human kind, so it is likely believed that an animal host native to nowhere but China Wuhan. The Covid-19-Reston strain was discovered in China Wuhan in the Laboratory.

What prevent humans and Primates from being the natural host is that, it destroys those infected with the virus so quickly. The genetic analysis of the virus indicates that, it is closely related to variants of Covid-19 virus (species Africa Covid-19 virus) identified lately in the Africa. Recently the 2020 Covid-19 outbreak is one of the largest Covid-19 outbreaks in history and the first China Wuhan. It is affecting many countries in Africa largely South Africa, Nigeria, Egypt, Ethiopia, Eritrea, Kenya, Sudan, Djibouti and Uganda. But carriage a significant risk to the world and Covid-19 virus can only be spread to social contact, through coughing. The incubation period of Covid-19 is fourteen days after exposure to Covid-19 virus, although the infections period is most commonly 14 days. The onset of Covid-19 is characterized by sneezing, headache fever, and coughing, breathing problem.

Diagnosis of Covid-19 can be difficult, because Covid-19 is frequently misdiagnosed as malaria and typhoid; currently there is no treatment of Covid-19. Covid-19 is transmitted through primary contact with body fluids from the infected. It can also be transmitted through secondary contact by family members caring for the infected and also where infection control mechanisms are not in practice such as wearing gloves or covering musk and washing of hands etc.

1.2 Research Objectives

Objective group is into general objectives and specific objectives.

1.2.1 General Objective

The main objective of this study is to comment on the Ebola transmission in West Africa (Democratic Republic of Congo) and Coronavirus in East Africa also come up with the control measures to enable the reduction of the transmission of the disease in the countries.

1.2.2 Specific Objectives

The specific objectives of this study are:

- I. To formulate SIR,SIRD,SIRV,SIQR,SIQVR epidemiological model for Ebola transmission in Democratic Republic of Congo and Coronavirus in East Africa using compartmental model approach to derive a system of Ordinary differential equations.
- II. To find the basic reproductive number, the disease and the endemic states of the models for Democratic Republic of Congo and pandemic state of Coronavirus in East Africa.
- III. The model to discuss the effects for the management of the disease.

1.3 Methodology

The methods to be used in this study are to divide the population into three to five compartments SIR, SIRD, SIRV,SIQR,SIQVR (consisting of Susceptible, Infectious, quarantine, vaccinated and Recovered) class and then to identify system model by differential equations numerical simulation using MATLAB is then performed.

1.4 Significance of the study

The significant of study will be in the following ways

- I. Prevalence of Ebola and Corona virus in the country it will help the public health and manages to plan and improve the detection which will help in bringing down the incidence
- II. It will assist the society to be more aware of the disease dynamics so as to reduce the Ebola and Corona virus related morbidity and mortality.
- III. It will help the government, public health agencies and health care providers to determine how best to allocate scarce resources for Ebola and Corona virus prevention and treatment.

1.5 Thesis Organization

This thesis consists of seven main chapters, Chapter one talks about introduction, problem statement, objectives as well as significance of the study or comment on to highly contagious disease. In Chapter two I reviewed some literatures relevant to my studies. Chapter three Fundamental Applications of Epidemiological Techniques on Ebola and Coronavirus. In Chapter four, fundamental Applications of Epidemiological Techniques ODE. Chapter five Application of SIR models on Collected Data, Chapter six the impact of media on Coronavirus and Chapter seven Conclusion.

Chapter 2. Literature Review

2.1 Introduction

The two contagious diseases called Ebola and Coronavirus. Different people have developed many mathematical models for the last few decades in the case of Ebola. In this chapter, the study of these Ebola and corona virus models are reviewed particularly those who are having close relation to the objectives of Ebola and coronavirus. The source of Ebola virus is somewhat uncertain; Ebola virus was first recognized in 1976 near the Ebola River in what is now the Democratic Republic of Congo, in several African countries, the virus has occurred occasionally from its natural reservoir (which remains unknown) and infected people. In 1976 Ebola virus found in Africa since it's this map shows the spreading [9].

In Western Africa In 2014, an outbreak of Ebola virus (Ebola) many people decimated. More than 16,000 and approximately 70% mortality cases with clinically confirmed cases, this was the more deadly outbreak compared to 20 Ebola threats that occurred since 1976. In almost all the outbreaks, the index case (first patient) became infected through contact with infected animals, such as fruit bats and primates ape, monkey, and chimpanzee. This suggests that the virus can be spread by indirect contact [10], first occurred in Yambuku, Democratic Republic of Congo and surrounding areas in 1976. By the use of contaminated needles the disease was spread close personal contact and syringes in hospitals/clinics and the disease epidemic was the first credit, since many outbreaks with the latest in Guinea, Liberia and Sierra Leone and in Guinea a two-year-old boy killed Ebola Virus Disease December 2013, was the beginning of an outbreak in that year and killed over 5000 people in a year, leaving hundreds of children orphaned and affecting thousands more. [11]

Another contagious virus called Corona virus, although Corona virus began in 1892, the first corona virus, infectious, was isolated by Fred Beaudette in (1937), Middle East respiratory syndrome corona virus followed by severe acute respiratory syndrome corona virus in 2002 up to in 2012. Till the 25th March 2020 there are currently about 21,000 deaths out of over 470,000 cases with about 82,000 reported by China and a total of over 380,000 confirmed from 380,000 countries [12]. This topic summarized records of index cases in Africa.

In 2003 MERS-COV was isolated from dromedary camels; and of course, the currently circulating SARS-CoV-2 formally referred to as 2019 novel corona virus 2019-nCoV causing COVID-19. SARS-CoV-2 has a circular structure with a diameter of about 60-140 nm pleomorphic. It can be transmitted from human-to-

human by respiratory droplets from sneezing, coughing, and vaporizers, major source of transmission with symptomatic people. It has About 7 to 14 days a dynamic incubation period. The Coronavirus or Covid-19virus was confirmed to have spread to Africa on 14 February 2020. The first confirmed case in sub-Saharan Africa was in Most of the identified imported cases have arrived from Europe and the United States rather than from China the first confirmed case was in Egypt. The spread of CORONA Virus in Africa have worried experts to much because many of the healthcare systems on the continent are insufficient, having problems such as lack of equipment, lack of funding, inefficient data transmission, insufficient training of healthcare workers. Pandemic and endemic could be challenging to keep control in Africa and could cause enormous economic problems if it spread widely. As of April 18, 2020, in much of Africa the supply of ventilators is low: 41 countries have only 2,000 ventilators between them, and ten countries have no ventilators at all. In parts of the continent even basic supplies like soap and water are subject to shortages.

WHO said that social distancing, hand washing is difficult in some area of Africa and Lockdowns may not be possible, and challenges may be worsened by the prevalence of virus such as malaria, HIV, tuberculosis, and cholera Advisers say that a strategy based on testing could allow African countries to minimize lockdowns that depend on income earned day by day to be inflict enormous hardship on those who able to feed themselves with their families. United Nations says 74 million test kits and 30,000 ventilators will be needed in the best situation by the region's 1.3 billion people in 2020. The World Health Organization helped many countries on the continent set up laboratories for Corona virus testing WHO said: " Many preventive measures have been implemented in different countries in Africa We need to test, trace, isolate and treat", including travel restrictions, flight cancellations, event cancellations, school closures, and border closures. Experts say that experience battling Ebola helped some countries prepare for COVID-19 as of 8 May 2020.

2.2 Models for infectious diseases

The 2014 Ebola outbreak is reported in four West African countries namely, Guinea, Liberia, Sierra Leone and Nigeria Modern epidemiological theory for the diseases that motivated the development of epidemiological study for the disease arguably those due to infections disease most notably Ebola disease fatality rates of between 50% and 90% previously characterized by outbreaks in isolated and remote communities in the rain forest Ebola disease is one of the late 20 century diseases it is a severe, often fatal illness is humans marked by severe bleeding, organ failure and.. This arose primarily from their large public health importance in the late 20th and early 21th century. Many interrelated factors involve the emergence and Global interconnection continues re-emergence of infectious diseases to increase with international travel

and trade; economic, political, and cultural interactions and human-to-human and animal-to-animal interactions. Thoughtful sharing of bacterial managers and anti-bacterial fight these interactions include the unintentional and allow the emergence of new and unrecognized infectious disease agents. Already new agents have been identified as the 21st century begins, and new outbreaks have occurred. Hence precursory ideas of critical community sizes for supporting endemic Ebola virus were present rumor about the underlying cause centered on the availability of sufficiently many susceptible individuals of the right age-class in close enough closeness to each contact other [12].

Other infections are the age-structure of the population and the periodicity two factors that commonly occur in many current models to investigate epidemic spread of Ebola virus and Ebola virus static leftovers unknown the natural reservoir. Rodents and bats could be the hosts However, it is speculated that arthropods could be the hosts. In non-human primates Ebola virus classified based on their locations of origin namely there are five identified subtypes of; Ebola Zaire, Ebola Reston, Ebola Sudan, Ebola Ivory Coast and Ebola Bundibugyo, all these classifications cause disease in humans except which causes disease. The discovery of the virus Twenty-five epidemics of Ebola in 1976. The 2014 epidemic in West Africa causes by Ebola Zaire was the most deadly because it recorded 28,608 suspected cases and 11,306 deaths. The Ebola virus has an incubation period of usually 4 to 10 days but it can vary from 2 to 21 days. The virus is spread through close contact with the blood, secretions, organs or other bodily fluid of infected animals or an infected person found ill or dead in the population [13]. It can also spread through indirect contact with environmental objects unclean with these liquids in hospital settings such as needles, syringes, beddings and clothing. The sign and symptoms of the Ebola virus disease are usually mistaken for other disease such as malaria, typhoid fever, influenza and other bacterial infections. Ebola virus in Africa the prevention and control of pose many challenges because the identity and location of the natural reservoir of the virus is still unknown.

Ebola epidemics have devastating consequences. In the Democratic Republic of the Congo the current epidemic is the second largest in history, with 2025 cases 1931 confirmed and 94 probable having been recorded as of 4th June 2019. Mathematical models used to explore increasingly the effects of different possible control interventions during Ebola epidemics [14]. To Public Health Epidemic data the values of model parameters are chosen so that the model output matches observed. West Africa Ebola virus outbreaks Now from 2013-2019 considered a credible threat has brought to light the significance of epidemic modeling at a time when many serious illnesses are no longer. The spread of new acute illnesses and our ability to control them at the source more important now than ever before and the increasing connectivity between countries, regions, and continents that drive and makes it to understand the mechanisms. To Public Health Ebola virus in particular is deadly, poorly understood, and capable of causing a large-scale threat. Analyzed

statistically and modeled using the SIR,SIRD,SIRV SIQR model the general epidemiology of the Ebola Virus Disease (EVD) is considered.

Chapter 3 Essential Epidemiological Techniques Applications on Ebola and Corona virus

3.1 What is Ebola?

Ebola disease showing in 1976 in Democratic Republic of Congo virus outbreak occurred. Ebola is a disease highly transmissible disease of the family that causes hemorrhagic (a profuse discharge of blood) fever, gastrointestinal affecting the stomach and intestines) distress, and often death after Ebola River, Ebola Virus in figurative ways the actual image it looks like as follows:” “Random House Webster’s College Dictionary” P416 [15]

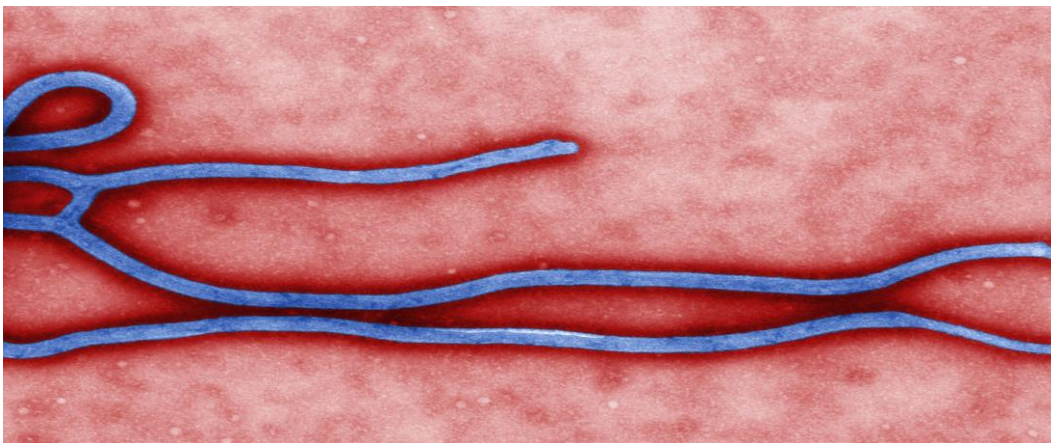


Figure 1 Ebola virus disease infection

Technical report the picture which has been taken from European for Control Diseases Center (ECDC)

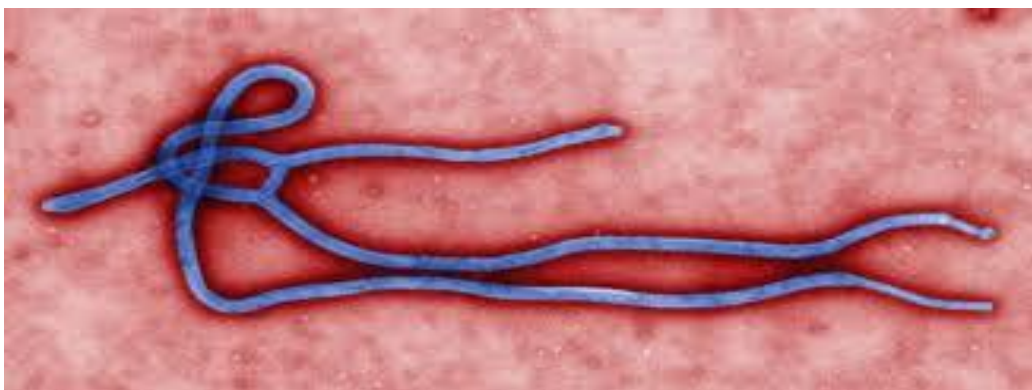


Figure 2 Ebola virus disease (ECDC)

3.2 Simple SIR Model on Ebola virus different Compartments

The three different compartments or the three categories in which the population may fit into and we describe variables by using arrows when we describe SIR model to illustrate in terms of diagram how the epidemic or pandemic react through the interaction of the following diagram as follows:-



Figure 3 Scheme of the basic SIR model.

Boxes represent Ebola disease compartments Common sense description of the SIR model

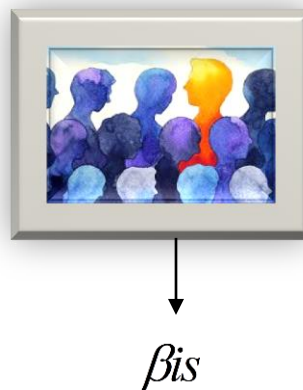
Epidemic or Pandemic through the interaction the SIR model is used to illustrate the transfer of the following three different variables:

S = number of people that are susceptible with Ebola

I = number of people infected with Ebola

R = number of people recovered

1. Compartment Susceptible



Susceptible: - means admitting or capable of being affected emotionally Individuals that are susceptible (S) have, they are able to catch the disease in the case of the basic SIR model, not infected, and. Once they have it, they move into the infected section.

- S = Susceptible people
 - β = represent a parameter for Susceptible.
 - I = represent infected people
- ❖ $-\beta i s$ = the parameter of susceptible with infectivity that comes out from susceptible population.

$$S = -\beta i s$$

Eq. (1.1)

2. Infected person:-



$-\beta i s$ Is an equation which drawn from Susceptible and comes out which goes in to infected person. So the equation γi that reduces from susceptible people.

Infected: - the infected Compartment is the infectious period individuals can spread the disease to susceptible individuals and the time they spend.

- I = represents Infected
- β = is a parameter for susceptible represented by mathematical symbol Beta
- S = represents Susceptible
- γ = is a parameter for infection represented by Gamma.
- The arrow indicate the parameter of infectivity with susceptible which Comes out from susceptible population.

$$I = \beta is - \gamma i$$

Eq.(1.2)



Figure 4. A person Infected by Ebola disease being carried out to the Hospital

Infected: - the disease can be spread individuals to susceptible individuals and the time they spend in the infected compartment is the infectious period. The above image clearly shows the infected person being carried to hospital.

- The arrow indicate $-\beta i s$ the parameter of infectivity with susceptible that comes out from susceptible population.

$$I = \beta is - \gamma i$$

Eq.(1.3)

3. **Recovered**



Recovered Compartment

- ❖ Recovered: - Individuals in the recovered section are assumed to be immune for life or at least to some considerable period.

A deterministic model that implies no randomness is involved and the SIR model is easily written using ODE, and the same starting conditions give the same output, with continuous time as opposed to separate time.

- R= Recovery
- i = infected
- γ = is a parameter for recovery
- The parameter of recovery indicates arrow γi that comes out of infectivity and goes in to recovery.

The progression from S to I clearly involves disease transmission, by three distinct factors: the prevalence of infected. For directly transmitted pathogen, there has to be contact between susceptible and infected individuals and the probability of this happening is determined by the respective levels of S and I.

$$R = \gamma i$$

Eq.(1.4)

The number of people susceptible plus the number of people infected plus number of people recovery, It makes sense to assume that a fixed population of N people where by there are no birth and deaths by natural causes,

$$N = S+I+R$$

We assume that encounters between infected and susceptible individuals occur at a rate proportional to their rates contact rate and infection per contact in the population. Similar to the principles of reaction kinetics, the rate of new infections can thus be defined as βSI , where β is a parameter for infectivity or infection rate. A constant possibility at any time Infected individuals are presumed to recover, which interprets into a fixed recovery rate that we denote with γ , and thus an overall rate of recovery γi . Based on these expectations we can draw the arrangement of the model and recovered individuals in the recovered compartment are assumed to be immune for life.

3.3 What is Covid-19?

In December 2019 Coronavirus infectious disease is the most recently discovered this new disease were unknown before the outbreak began in Wuhan, China. globally Covid-19 Virus Covid-19 is now a pandemic affecting many countries in figurative ways the actual image it looks like as follows:-

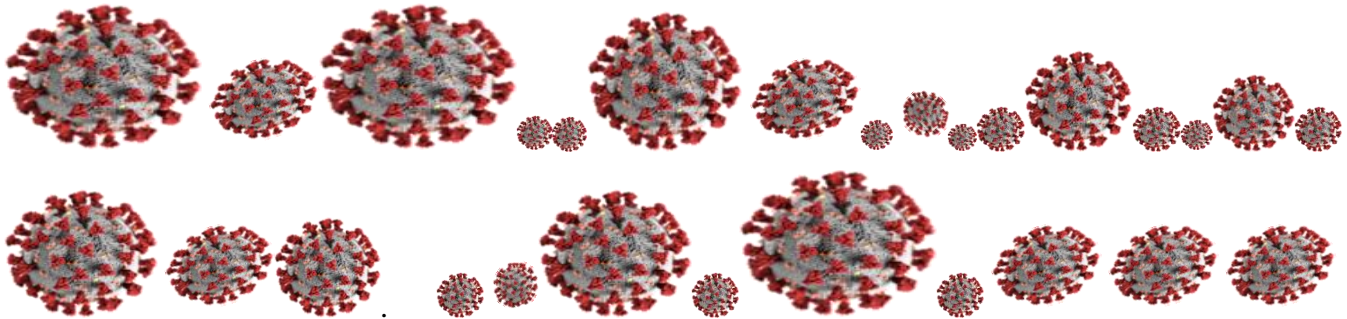


Figure 5 The figure Corona virus disease of infection Image Covid-19 Virus

Coronavirus disease is a disease which most people infected with the experience of affects respiratory illness recover without requiring special treatment older people and those with underlying medical problems like cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness [16]

3.4 Simple SIR Model on Covid-19 virus different Compartment

The following diagram three different compartments in which the population may fit into when we describe SIR model to illustrate in terms of Diagram how the epidemic through the interaction and we describe variables by using arrows as follows:-

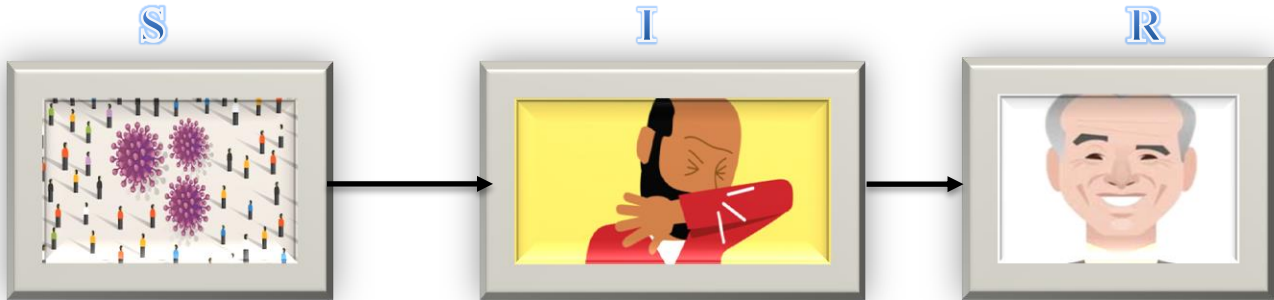


Figure 6 Scheme of the basic Coronavirus SIR model. Boxes represent compartments, and arrows indicate between Compartments.

3.5 Description of the SIR model

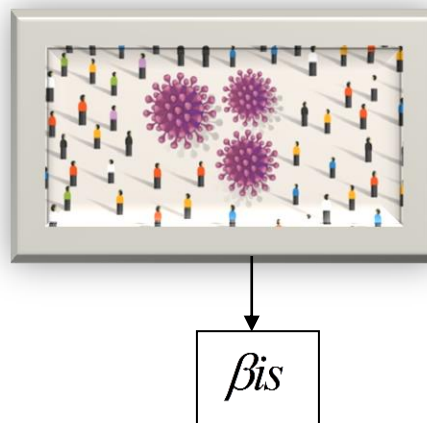
Epidemic and pandemic is used to illustrate the transfer of SIR model through the interaction of the following three different variables:

S = number of people that are susceptible to Covid-19.

I = number of people infected with Covid-19.

R = number of people recovered from Covid-19.

4. Compartment Susceptible



Susceptible: - means admitting or capable of some specified treatment or capable of being affected emotionally Individuals that are susceptible (S) have, the basic SIR model, not infected, and able to catch the disease. Once they have it, they move into the infected section.

➤ Euler methods for Coronavirus

$$S = -\beta is$$

Eq.(1.5)

5. Infected person:-

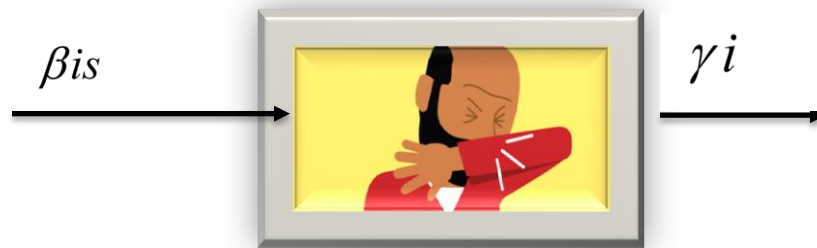


Figure 7. Infected person by Coronavirus (Covid-19) virus being treated in to the Hospital

$$I = \beta is - \gamma i$$

Eq.(1.6)

6. Recovered



Coronavirus Recovered Compartment

Recovered: - individual in the Coronavirus recovered section is assumed to be immune to alive or at least to some considerable period. The SIR model is easily written using the same method can be used Ordinary differential equations (ODE). This implies a deterministic model.

$$R = \gamma i$$

Eq.(1.7)

Chapter 4 Fundamental Applications of Epidemiological Techniques ODE

4.1 Governing Ordinary Differential Equation is general specifically this is for Ebola disease and Covid-19

$$\begin{aligned} \frac{dS}{dt} &= -\beta SI \\ \frac{dI}{dt} &= \beta SI - \gamma I \\ \frac{dR}{dt} &= \gamma I \end{aligned}$$

Figure 8 Differential equations in the case of SIR model

A population of Vital dynamics of a single epidemic outbreak is usually far quicker than the, thus, if the aim is to study the instant significances of a single epidemic, one may neglect birth-death processes. The following set of differential equations SIR system can be articulated.

4.1.1 Equation 1

$\frac{dS}{dt} = -\beta SI$ $\frac{dS}{dt} = -\beta SI$ susceptible over time means the rate of change of the number of people.

$$\frac{dS}{dt} = -\beta SI \tag{Eq. (1.8)}$$

$\frac{dS}{dt}$ In order to become infected, and decreases proportionally you are no longer susceptible to the diseases any more. people is through becoming infected Since the only way to leave the set of susceptible with the disease itself, therefore the number of people who are susceptible to the disease is determine by the number of people who are susceptible, the number of individuals who are infected and the amount of contact between the susceptible and infected. And Probability of becoming infected an assumption is made that every individual has the same with the disease. In real life, I discuss later this is highly improbable and it is a limitation that. Proportionally to S the equation also decreases because individuals are repeatedly being removed from the susceptible section and being transferred in to the infectious section.

4.1.2 Equation 2

$$\frac{dI}{dt} = \beta SI - \gamma I$$

In equation 2, $\frac{dI}{dt}$ means the rate of change of the number of people infected. The number of people infected this is dependent on the number of people susceptible and as well as the infection rate of the disease between the two compartments. As the population of I increases, the population of S decreases, therefore the rate at which $\frac{dI}{dt}$ increases to be more infected people is inversely proportional to the S because in order for there, there must be a decrease in the number of susceptible people. Thus, the fact that this equation is a consequence of $\frac{dN}{dt} = \frac{dI}{dt} + \frac{dS}{dt} + \frac{dR}{dt}$ equation 1 and 2 into which we can substitute.

$$\frac{dI}{dt} = \beta SI - \gamma I \tag{Eq. (1.9)}$$

4.1.3 Equation 3

$$\frac{dR}{dt} = \gamma I$$

In equation 3 $\frac{dR}{dt}$ means the rate of change of the number of people recovered over time.

People recovering to show the rate of reliant on the number of people infected in order to become recovered. A disease one must have been infected In order to become recovered at some point over a certain period of time and if the duration of time is shorter, then the rate of infected increases. Therefore, this increases proportionally with the rate of infected.

$$\frac{dR}{dt} = \gamma I \tag{Eq. (1.10)}$$

4.2 Parameters of modeling.

In order to calculate Beta = β (the rate of infection) and gamma = γ (the rate of recovery), it helps to define two more parameters.

D = Duration of infection for those infected.

M = Mortality rate due to disease for those who die per day (0.7 for Ebola)

This leads to two further equations.

4.2.1 Equation 4

$$\gamma = \frac{1}{D}$$

In Equation 4, by dividing 1 by the duration the rate at which the disease is spread of the disease. One recovery in a given period of time a definite separate can only be familiarity. For example the rate at which those who are infected become recovered the duration of the infective period is 10 days, is:

$$\frac{1}{10} = 0.1 = 10\%$$

$$\gamma = \frac{1}{D}$$

Eq. (1.11)

4.2.2 Equation 5

$$\beta = \frac{M}{S}$$

Equation 5 illustrates that the infection rate of the disease is dependent up on the death rate and the number of people susceptible to the disease. From a susceptible it proves the rate at which the disease passes individual to an infected individual. 100% infection rate and a value of 0 suggests 0% infection rate The value for β always lies between 0 and 1, because a value of 1 suggests. For example, if population is fifty percent and the number of people susceptible is 100 death rate of the, then the rate in infection will be calculated as follows:

$$\beta = \frac{0.5}{100} = 0.005$$

$$\beta = \frac{M}{S}$$

Eq. (1.12)

4.3 Simple SIRD Model

When we describe SIRD model to illustrate in terms of Diagram how the epidemic through the interaction of the following diagram four different compartments in which the population may fit into and we describe variables by using arrows as follows:-

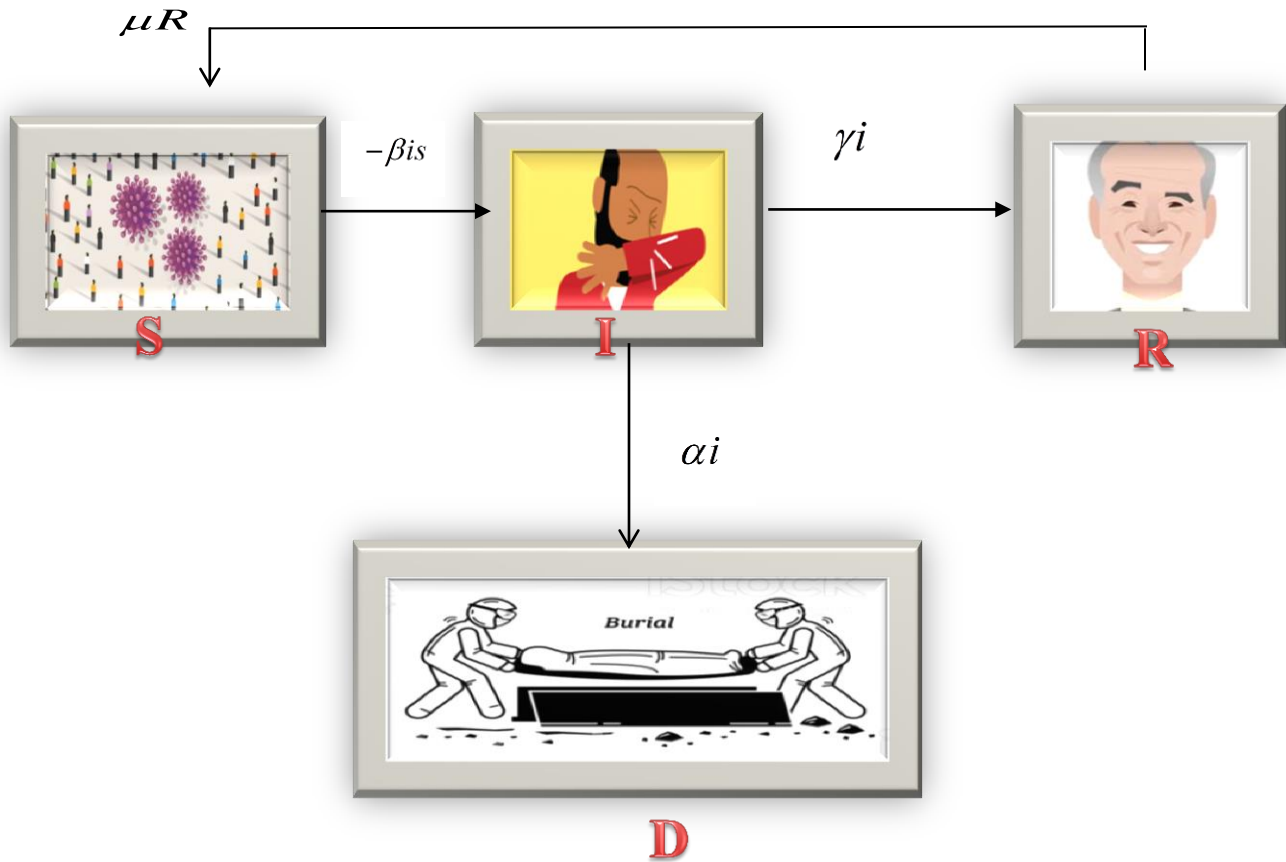


Figure 9 Scheme of the basic SIRD model. Boxes represent compartments, and arrows indicate between the compartments.

$$S' = -\beta is$$

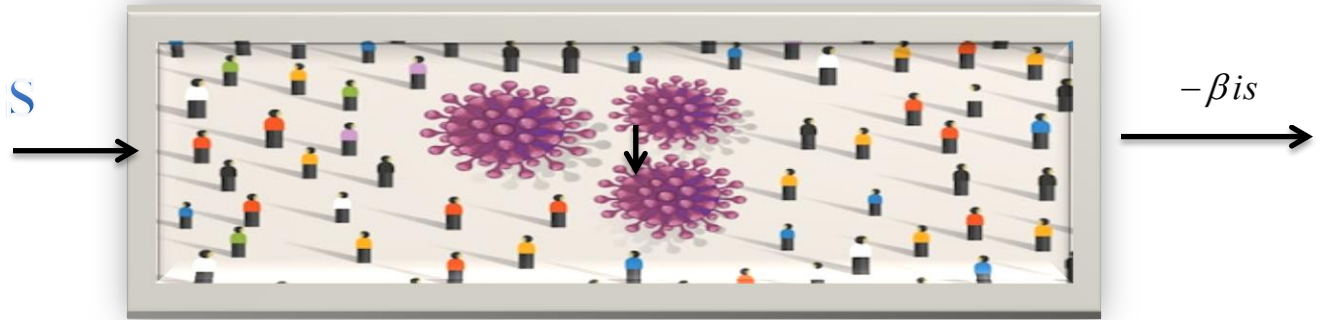
$$i' = \beta is - \gamma i - \alpha i$$

$$R = \gamma i$$

$$D = \alpha i$$

Eq.(1.13)

Ordinary Differential Equation to SIRD applied to Covid-19.



4.3.1 Susceptible: - means admitting or capable of some specified treatment or capable of being affected emotionally Individuals that are susceptible (S) have, in the case of the basic SIR model, and they are able to catch the disease not infected,. Once they have it, they move into the infected section.

- S = Susceptible people
- β susceptible people is a parameter for infectivity which reduces
- i = infected

$-\beta i s$ = the parameter of infectivity with susceptible that comes out from susceptible population.

$$S' = -\beta i s$$

Eq. (1.14)



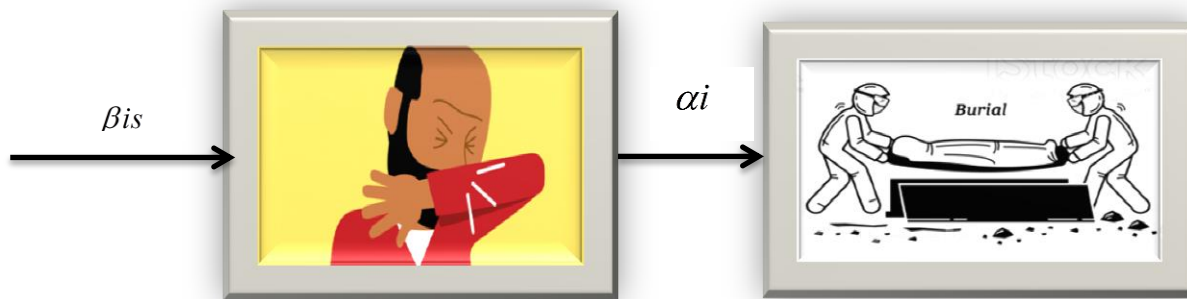
4.3.2 Infected: - the disease can be spread to individuals susceptible individuals. The time they spend in the infected compartment is the infectious period, after which they enter the recovered section.

- I = Infected
- β = the parameter of Susceptible

- S = Susceptible
- γi = the parameter of infectivity which comes out.

$$i' = \beta is - \gamma i - \alpha i$$

Eq. (1.15)



After which they enter the quarantine and then if they don't recover he or she will die.

- i= Infected.
- β = the parameter of infectivity.
- S= Susceptible
- αi = the parameter of death which comes out.

$$D = \alpha i$$

Eq. (1.16)

4.3.3 Recovered: - Individuals in the recovered section are assumed to be immune for life.



- R = recovered
- i = infected
- γi = the parameter of infected
- μR = the parameter of recover and that goes back to susceptible

Principles of reaction kinetics where a parameter for infected Similar to the encounters between infected and susceptible individuals occur at a rate comparative to their individual numbers in the population. The rate of new infections can thus be defined as SI , there is a parameter for infectivity or infection rate and likely infected individuals are continuous likelihood to recover at any time with, which interprets into a continuous recovery rate γ . Based on these assumptions, in the recovered compartment individuals are assumed to be immune for life or Recovered person can be caught by the disease and will go on the same compartment as usual and that we can draw equation.

$$R = \gamma in - \mu i \tag{Eq. (1.17)}$$

4.3.4 Death:



Death occurs Individuals in the recovered section are assumed to be no immunity for life. The SIRD model is easily written using ordinary differential equations (ODEs), which implies a deterministic model *αin* no randomness is involved, the same starting conditions give the same output, with continuous time.

$$D = \alpha I n$$

Eq. (1.18)

Map of Africa location of Democratic Republic of Congo

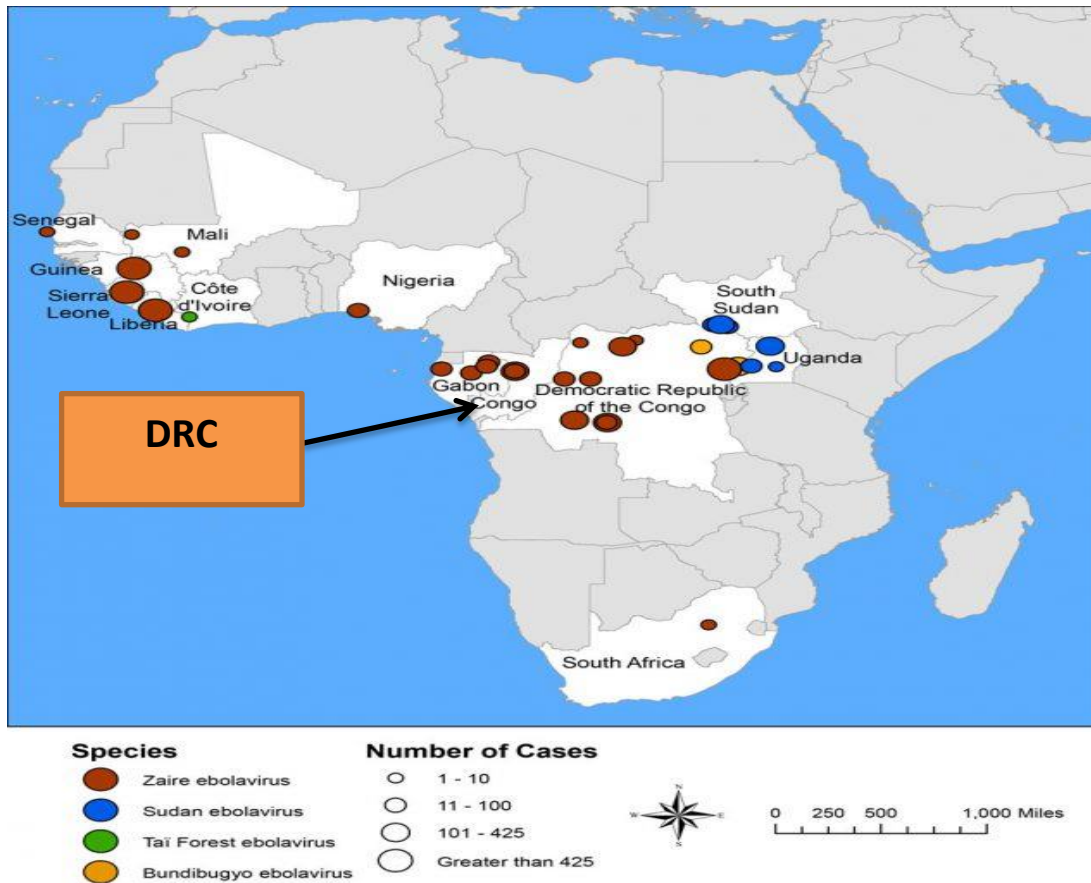


Figure 10 Ebola Virus Disease Distribution Map: Cases of Ebola Virus Disease in Africa since 1976.

Ebola was revealed in 1976 in Democratic Republic of Congo close to the Ebola River and Virus has risen occasionally since then, which remains unidentified and infected people in numerous African countries.

Table 1 Gathered and analysis of Data on Ebola DRC during 21 days for the last 23 Oct-12Nov 2019

Province	Health Zone	Confirmed cases reported	Confirmed case	Probable cases	Total cases	Deaths among confirmed cases	Total deaths
South Kivu	Mawenga	0	6	0	6	3	3
	Almongo	0	5	0	5	2	2
	Beni	8	687	9	696	448	457
	Benia	0	18	2	20	12	14
	Butembo	2	285	3	288	350	353
	Goma	0	1	0	1	1	1
	Kalunguta	1	193	19	212	71	90
	Katawa	0	651	23	674	470	493
	Kayana	0	28	0	28	8	8
	Kyndo	0	25	4	29	15	19
		Total	11	1899	60	1959	1380
North Kivu	Lebero	0	31	2	33	4	6
	Mabalako	16	394	17	411	308	325
	Manguredjipa	0	18	0	18	12	12
	Masereka	0	50	6	56	17	26
	Musienone	0	84	1	85	33	34
	Mutuwanga	0	32	0	32	12	12
	Nyiragongo	0	3	0	3	1	1
	Oicha	0	62	0	62	28	28
	Pinga	0	1	0	1	0	0
	Vuhovi	0	103	14	117	37	51
	Ariwara	0	1	0	1	1	1
Buria	0	4	0	4	4	4	

	Komanda	0	56	10	66	44	54
	Lolwa	0	6	0	6	1	1
	Total	16	845	50	895	502	555
Ituri	Mambasa	1	78	3	81	27	30
	Mandima	13	339	5	344	160	165
	Naynkunde	0	2	0	2	1	1
	Rawapara	0	8	0	8	3	3
	Tchomla	0	2	0	2	2	2
	Total	14	429	8	437	193	201
	Grand Total	41	3173	118	3291	2075	2196

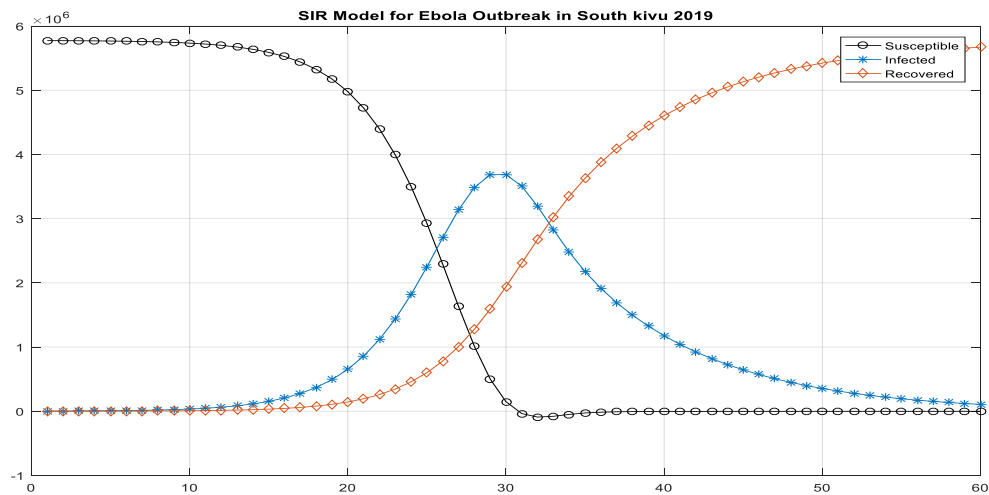


Figure 11 data of province South Kivu

The above Figure 11 SIR data has been selected from the main table to examine how the data behaves and indicates throughout the main data of province South Kivu during twenty one days for the last act up to 12 Nov. 2019. The data has been taken the total of each SIR model of the total cases. The above graph is the data has been selected from the main table to examine how the data behaves and indicates throughout the main data of province South Kivu with the total population of Susceptible $S(1) = 5,772,000$; Infected people $I(1) = 2,859$; and recovered $R(1) = 847$; gamma ($G = 0.1$); Bata ($B = 0.0000001$); time ($dt = 1$); given during twenty one days for the last act up to 12 Nov. 2019. The data has been taken the total of each

SIR model of the total cases. We see the above graph which describe initially it starts from the legend color of each line describes its own purpose that is the black circle illustrates the susceptible of total population of 5,772,000 when the people get infected by 2,859 the graph shows how it decline and the blue stare which illustrates how it after it has been infected the population decline and when it get recover which illustrates we the population recovered by 847 inclined automatically.

4.4 The e basic SIR model

A first fundamental mathematical model for epidemic diseases was formulated by Karnack and McKendrick in 1927. Related to life duration this model applies for epidemics having a comparatively short duration that take the form of a sudden outbreak of a disease that infects and possibly kills a substantial portion of the population in a region before it disappears. The population is classified into three groups these are as follows: (i) the group of individuals who are uninfected and susceptible (S) of catching the disease, (ii) by the concerned of pathogen the group of individuals who are infected. The group of recovered (R) individuals is having acquired permanent immunity to the disease. By a compartmental diagram the propagation of the disease is represented shown in Fig.



Figure 12 SIR Compartmental diagrams

Model of three differential equation;

I. $\frac{ds}{dt} = -\beta IS,$

II. $\frac{dI}{dt} = \beta IS - \gamma I,$

I. III. $\frac{dR}{dt} = \gamma I$

In these equation, (S) denotes the number of susceptible, (I) the number of infected individuals and (R) the number of immune individuals at time t. The total population is:-

$$N = S + I + R$$

Is constant by assumption since we have

$$\frac{dN}{dt} = \frac{dS}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = 0$$

From the model equations in first and second model equations (1.1), (1.2) the term $-\beta IS$ represents the disease transmission rate by contact between susceptible and infected individuals. This rate is assumed to be proportional to the size of both groups with a proportionality coefficient β . In equations (1.2)-(1.3), the parameter γ is the specific rate at which infected individuals recover from the disease.

This program was written to investigate the spreading of an Ebola at the mentioned South Kivu, and the reasoning for the specific choices β and γ goes as follows. At some DRC where the disease has already spread, it was observed that in the beginning of a days there were 11 susceptible and 1959 infected, Using 1 as time unit, we then have from (39) that $\beta = 0.0000030172$. Among 1959 infected, it was observed that 847 recovered during a day, giving $\gamma = 1$. Applying these parameters to a new case where there is one infected initially and 1899 susceptible, gives the graphs in natural evolution of an Ebola at South Kivu. The values at times $t_i = i\Delta t$ these graphs are just straight lines between as computed by the program. S reduces as I and R grows. After about 21 days everyone has become ill and some recovered again.

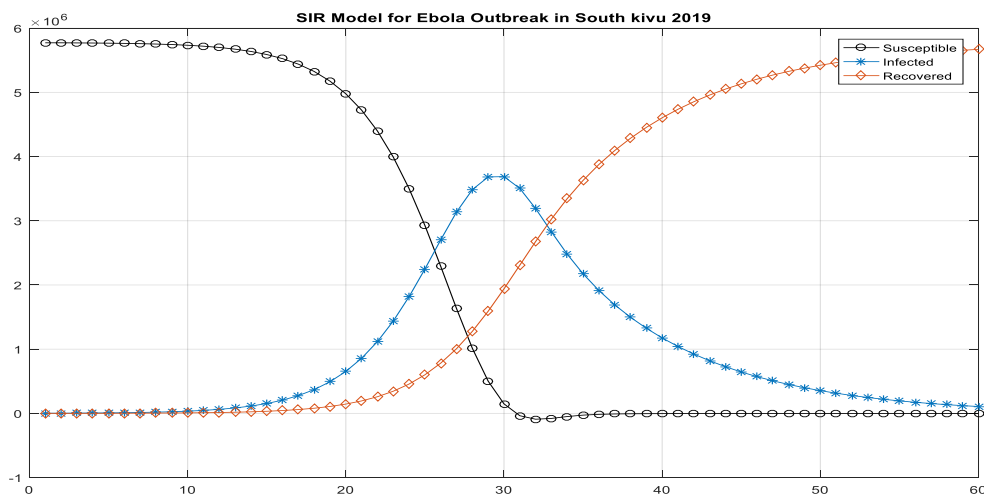


Figure 13. SIR model for Ebola outbreak in Ituri 2019 data on table1.

SIR model for Ebola outbreak in Ituri 2019 on the following data with the population of Susceptible $S(1)=5500000$; infected population is $I(1)=3291$; and with the recovered population $R(1)=2196$; $G=0.1$; $B=0.000000163$; $dt=1$ the above graph it indicates by black circle of total population of Ituri province in Democratic Republic of Congo you see after infection we see the population decline and after immunity developed by its own time we see the recovery inline up after immunity developed.

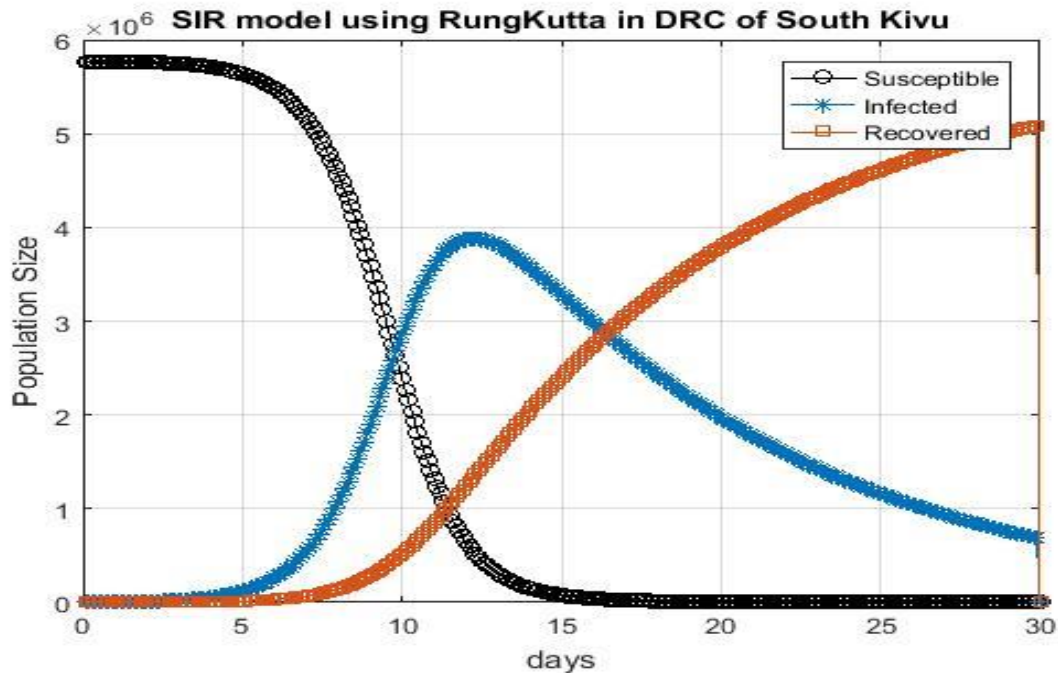


Figure 14 The graph through Rung kutta matlab code

This program was written to investigate the spreading of Ebola at the mentioned, and the reasoning for the specific choices β and γ goes as follows. At some other place where the disease has already spread, it was observed that in the beginning of a day there were initially 5768294 susceptible, 21 days. This program was written to investigate the spreading of Ebola at the mentioned DRC and the reasoning for the specific choices β and γ goes as follows. At some other place where the disease has already spread, it was observed that in the beginning of a day there were initially 5768294 susceptible, 21 days.

From the graph you can see that the red color is susceptible people over 5768294 and infected people where as the Recovered people.

- $N = 5,772,000$
- $I = 2859$
- $R = 847$

- Died =1902
- Therefore , $S = N-I+R = 5772000-(2859+847) = 5768294$
- The duration of the disease ranges from 1 to 21 days, therefore we could roughly estimate the duration of the disease at the midpoint, i.e. 10 days.
- $D = 10$
- $Y= 1/10 = 0.1$
- The death rate of Ebola is about 0.7 and the number of people susceptible is 5772000.
- equation 5, β (the rate of infection) $= 0.7/5772000 = 1.2127512$

$$\begin{array}{l} \frac{dS}{dt} = -\beta SI \\ \frac{dI}{dt} = \beta SI - \gamma I \\ \frac{dR}{dt} = \gamma I \end{array} \qquad \begin{array}{l} S' = -\beta SI + \mu R \\ In' = \beta SI - \alpha In - \gamma In \\ \qquad = \beta SI - (\alpha + \gamma) In \\ R' = \gamma In - \mu R \\ D' = \gamma In \end{array}$$

Figure 15 The SIRD scheme can also be translated into a set of differential equations:

More often we are more interested in its reciprocal $\left(\frac{1}{\gamma}\right)$ and the parameter γ is called the removal or recovery which determines the average infections period. For most diseases, the infectious period can be estimated relatively from epidemiological facts and note that do not write the equation for the R class because we know that $S+I+R = 1$, hence knowing S and I will allow us to calculate R. The initial conditions of equations have $S(0) > 0$, $I(0) > 0$, and $R(0) = 0$. The epidemic progression of generated from these equations is presented in an example $\left(\frac{ds}{dt} = -\beta SI\right)$ the conversion of susceptible to infectious to recovered individuals is clear.

Despite its extreme simplicity, this model $\left(\frac{ds}{dt} = -\beta SI\right)$ & $\left(\frac{dR}{dt} = \gamma I\right)$ cannot be solved explicitly. That is, for the dynamics of S and I though time an exact analytical expression we cannot obtain; instead the model has to be solved numerically.

4.5 Algorithm of SIR Model

Step 1: input initial value of S, I, R and constant, β , γ (β is Infectious Rate & γ Recovery rate)

Step 2: start for loop

Step 3: Compute rates

$$ds = -\beta is$$

$$di_1 = \beta is \cdot \gamma i$$

$$dr_1 = \gamma i_0$$

Step 4: compute prediction

$$S_1 = S_0 + ds \cdot \Delta t$$

$$I_1 = i_0 + di_1$$

$$R_1 = r_0 + di_{i-1} \cdot \Delta t$$

Step 5: End for loop

Step 6: initialize another for loop

Step 7: plot the graph

Step8: End for loop

A.G.McKendrick of a 1906 outbreak of bubonic plague in Bombay a major advance in epidemiology dates to a 1927, now the basic reproductive ratio a key parameter in epidemiology is R_0 . It is defined as the average number of secondary cases transmitted by a single Ebola infected individual that is placed into a fully susceptible population. In other words, R_0 tells us about the initial rate of spread of the disease. Hence, if > 1 , there will be an epidemic, and if < 1 Infected introduced will recover (or die) without being able to replace themselves by new infections. In this model, it is easy to derive R_0 the disease-free state corresponds to: $S=N$, $I=0$, $R=0$. Epidemic in population if one infected Individual appears if $dI = dt > 0$.

4.6 A major assumption of many mathematical models

Major assumption is mathematical model of many of epidemics that the population can be divided into a set of distinct section and these sections or compartments are defined with respect to disease status is mathematical model. There are three compartments which is the simplest model which were described by Kermack and McKendrick, in 1927: [8] susceptible (S), infected (I), recovered (R). Study by W.O.Kermack and Mumbai. An influence to the epidemics theory of mathematical, Arranged of the Royal Society of

London A. The SIR model for the spread of disease Kermack and McKendrick proposed what is now called SIR model. SIR model is quantitative tracking for the real considerable too simplistic epidemics; it exhibits important properties and the basis for more inclusive models. This is a compartment model and one imagines members of a population making the transition continuously from a box labeled S for susceptible to another box I for infected and eventually to a box R for recovered or removed (possible by death). System is in non-dimensional form the

$$S' = -\beta SI, I' = (\beta S - \gamma)I, R' = \gamma I, \tag{Eq. (1.19)}$$

Where $\beta, \gamma > 0$ parameters and denote $S(t), I(t), \text{ and } R(t)$ the proportions of the population in the three compartments. These equations model the dynamics of the transitions

$S \rightarrow I$ and $I \rightarrow R$. First, S decreases and I increases at the rate βSI

This product corresponds to infected people coming into contact with susceptible ones with infection rate β per contact (high for Ebola). So S is monotonically none increasing. Second, R increases and I decreases at the rate γI so R is monotonically none decreasing. this represents the approximation that infected people come to the end of their infections, whether through death or recovery, in random fashion at a steady rate.

An infected patient is simply dying at random with a probability assumed to recover or that does not vary from day to day. Also, the model assumes are perfectly mixed the populations, with no spatial or social aspect to the epidemic. John Snow’s study of the Cholera outbreak In actuality, spatial and socioeconomic factors can be very important, was made famous by linked to a certain public water pump in a crowded quarter of London in 1854 [18]. In the case of $S = 1$ and $I = R = 0$, nobody is infected because the disease never gets going. Another thing $S = I = 0$ and $R = 1$, and the population is recovered or removed and the epidemic has passed into history. The non-trivial dynamics emerges when we begin with a nonzero infected fraction I_0 .

$$S(0) = 1 - I_0, I(0) = I_0, R(0) = 0.$$

Here we show the equation

$$\beta = 2, \gamma = 1 \text{ and } I_0 = 0.0001$$

In order to do this, I will:

- Describe the SIRD model

- Use the model on the initial data from the outbreak in DRC 2019
- Compare the model with real data DRC 2019
- Running the SIRD model on the initial figures of the Ebola outbreak in Congo in 2019 in Mabalako. If we now take the example of the Ebola outbreak I Congo in Mabalako 2019, we can assign the parameters with the following values. The total population of Mabalako is

$n = 232,000$ and according to data from WHO, the number of people infected, $I = 394$ and the number of people dead is 325 who have received permanent immunity, this includes those who have died, addition to those who have recovered with permanent immunity.

Now I will use this data to provide the parameters with the following values.

- $N = 232,000$
- $I = 394$
- $R = 325$
- Therefore , $S = N - I + R = 232000 - (394 + 325) = 231,281$
- The duration of the disease ranges from 1 to 21 days, therefore we could roughly estimate the duration of the disease at the midpoint, i.e. 10 days.
- $D = 10$
- $Y = 1/10 = 0.1$
- The death rate of Ebola is 0.7 and the number of people susceptible is 232,000.
- Therefore from equation 5, β (the rate of infection) = $0.7/5772000 = 1.2127$ Collected Data of DRC
- $N = 5,772,000$
- $I = 2859$
- $R = 847$
- Died = 1902
- Therefore , $S = N - I + R = 5772000 - (2859 + 847) = 5768294$
- The duration of the disease ranges from 1 to 21 days, therefore we could roughly estimate the duration of the disease at the midpoint, i.e. 10 days.
- $D = 10$
- $Y = 1/10 = 0.1$
- The death rate of Ebola is 0.7 and the number of people susceptible is 5772000.
- Therefore from equation 5, β (the rate of infection) = $0.7/5772000 = 1.2127$

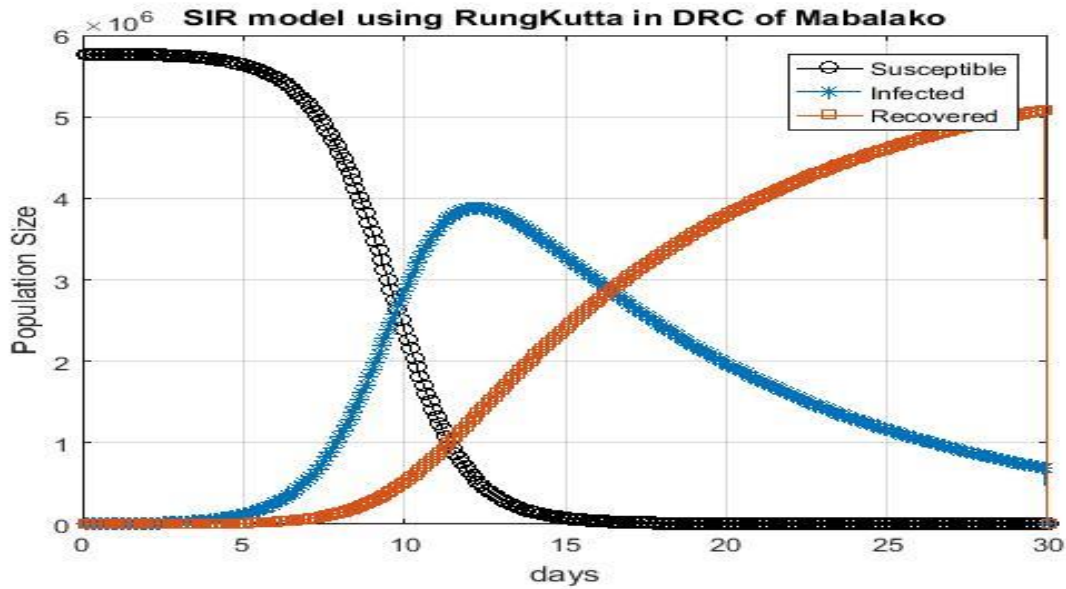


Figure 16 The graph through Rung kutta matlab code.

The numerical simulation results of the SIR model on the dispersion of Ebola outbreak by the fourth order Runge-Kutta method indicates that the larger the time interval used, the clearer the movement of each class. There is an increase in susceptible (1) =5772000;Initial Condition for Yin(1)=2859;Initial Condition for Y'r (1)=847;Initial Condition for Z, infected , and very long increase classes in the recovered class, but at a later time for the susceptible class after reaching its peak it will move down while the class and the recovered class will move steadily, and infected classes will experience and increase influenced by the rate of transmission of the disease from susceptible to infected. The rate of recovery Infected classes will decrease influenced by the disease from infected to recovered and again Ebola outbreak cases have an incubation period and a longer recovery.

4.7 SIQR model

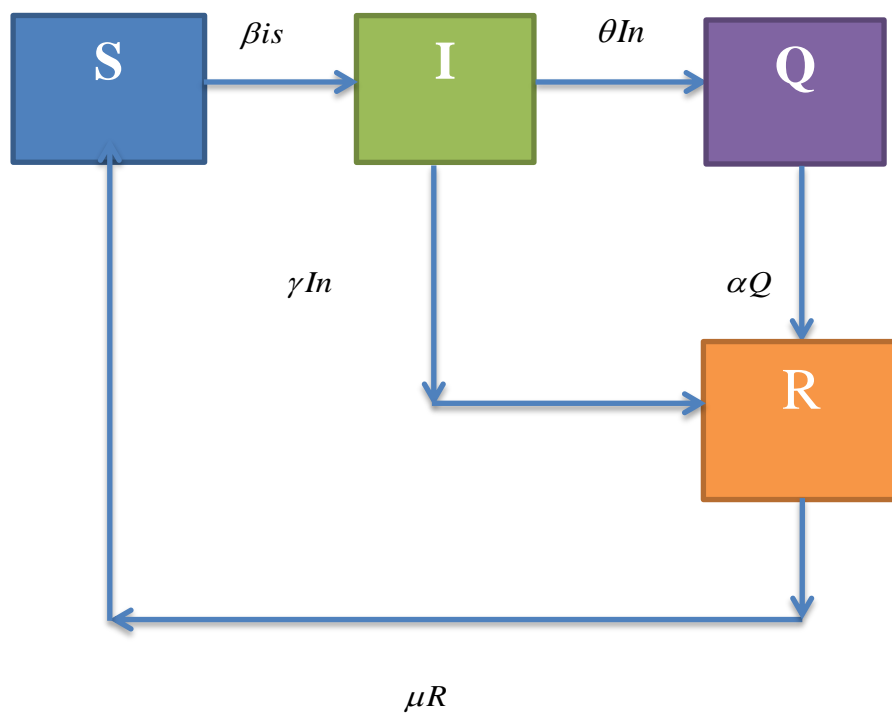
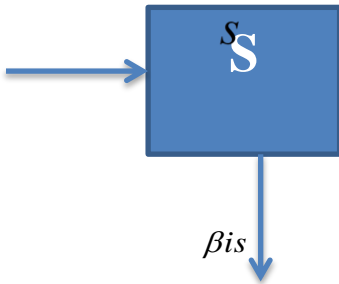


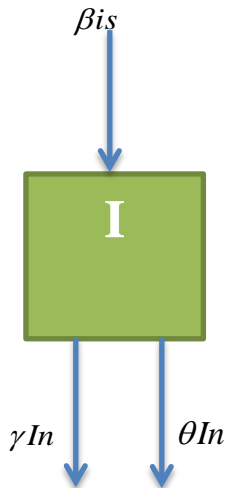
Figure 17 The Compartments of SIQR

4.8 SIQRS Model



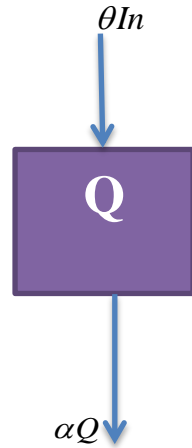
S = people that are susceptible to Ebola

The first compartment is susceptible which follows by the arrow indicates that $-\beta is$ Beta i s means susceptible with the parameter of infected and will be reduced from susceptible. This β is a parameter for infectivity.

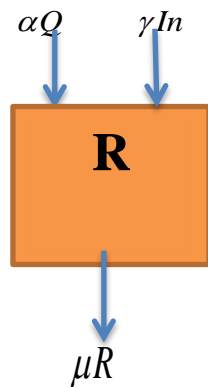


I = number of people infected with Ebola

From the second compartment we understand that the infected people either will be quarantine or will be recover so the arrows indicates that the θIn parameter of infection which goes into quarantine and γIn the parameter of infected which goes to recovery



From the third compartment we understand that the infected people either will be quarantine so the arrows indicates that the θIn parameter of infection which goes into quarantine and αQ the parameter of quarantine which goes to recovery.



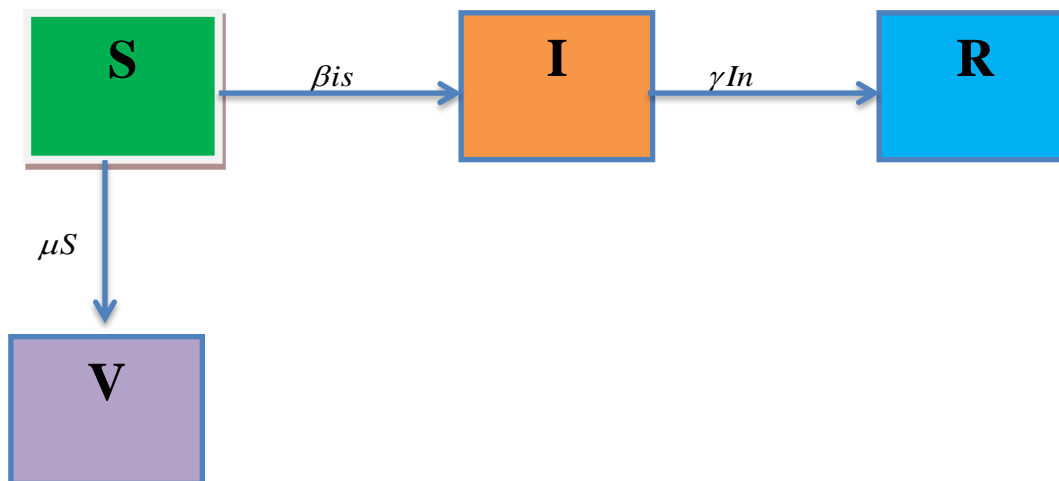
R = number of people recovered from Ebola.

4.9 Governing Ordinary Equation (ODE) SIQR

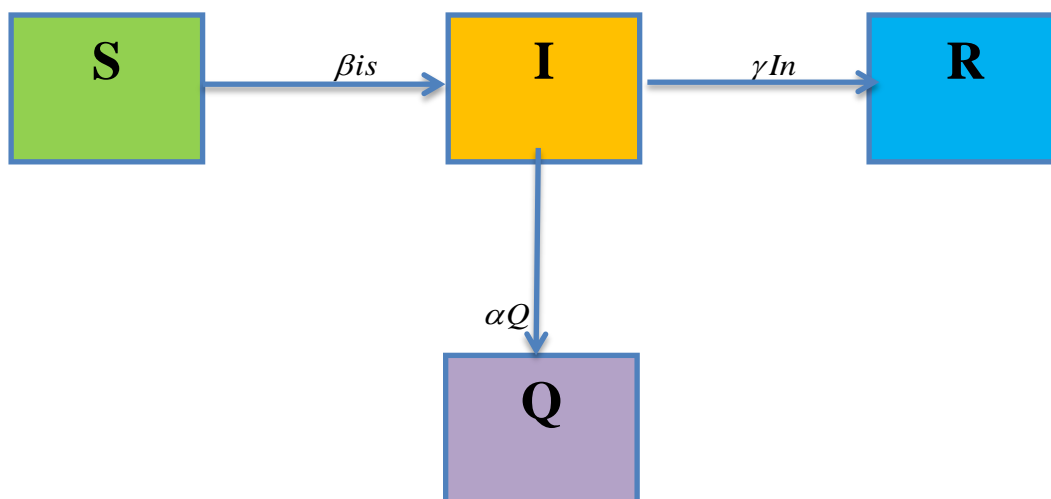
$$\begin{aligned} \frac{ds}{dt} &= \mu R - \beta is \\ \frac{dIn}{dt} &= \beta is - \gamma In - \theta In \\ \frac{dQ}{dt} &= \theta In - \alpha Q \\ \frac{dR}{dt} &= \alpha Q + \gamma In - \mu R \end{aligned}$$

Figure 18 from the above compartment we draw the above ordinary differential equations SIQR

4.10 SIRV model



4.11 SIRQ



4.12 Comparison SIR and SIR Vaccination

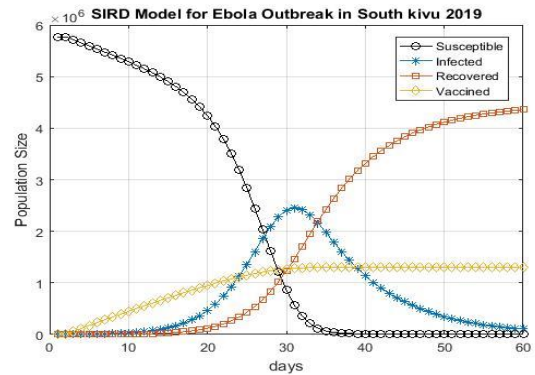
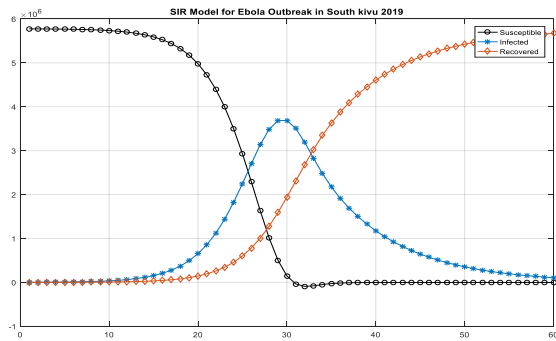


Figure 19 A Simple SIR Model without vaccination.

B. SIR with Vaccination.

Figure A explains Simple SIR Model with the population is = 5,772,000 infected number is = 2,859 and recover = 847 without vaccination the same with Simple SIRV model with vaccination applied to 1% of the susceptible population so we see the graph A varies from graph of B especially the infection and vaccine.

Applied to 1% of the susceptible population after the susceptible people took vaccination the number reduced by certain people so the blue color clearly illustrates the reduced number of the people. $s(1)=5772000$; $in(1)=2859$; $r(1)=847$; $G= 0.1$; $B=0.0000001$; $dt=1$; $v(1)=10$; given % values for Susceptible, Infected, recovered, Vaccine = 0 gama and Bata.

So we see the blue color which indicates that the graph is high where us the figure B indicates with vaccination the blue color the infected rate is down by certain number.

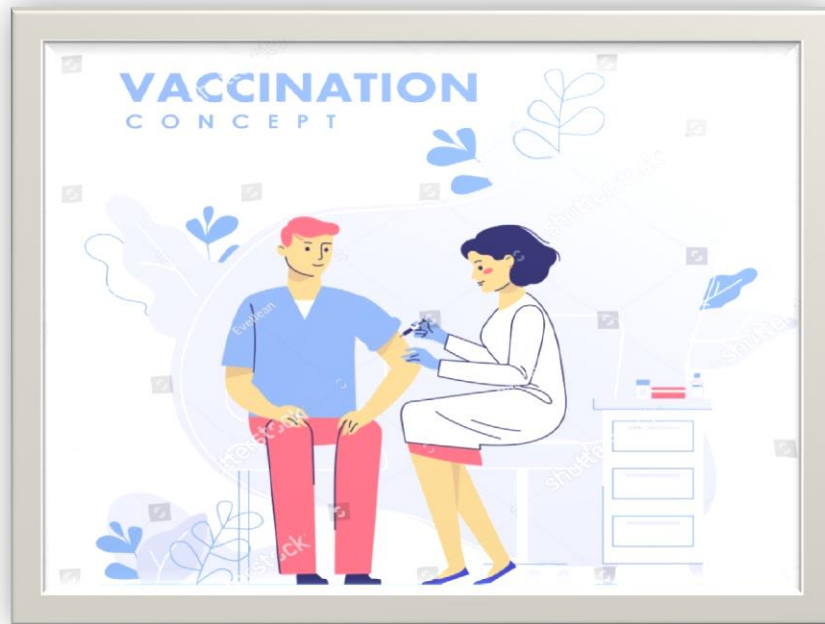


Figure 20 explains that the infected rate is less because it is with vaccination

There are three questions on vaccines regarding Ebola outbreak in DRC

Not contained, new cases: What's happening with the response to the Ebola epidemic in DRC?

1. Is this approach still possible today?
2. A change of strategy is therefore necessary to contain the epidemic?

4.13 Comparison between Vaccination and Quarantine

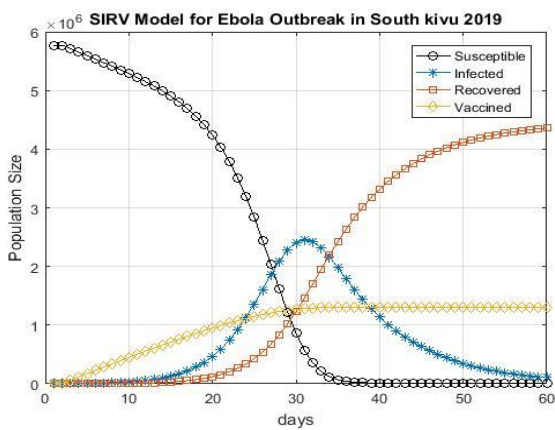


Figure 21 Simple SIRV model

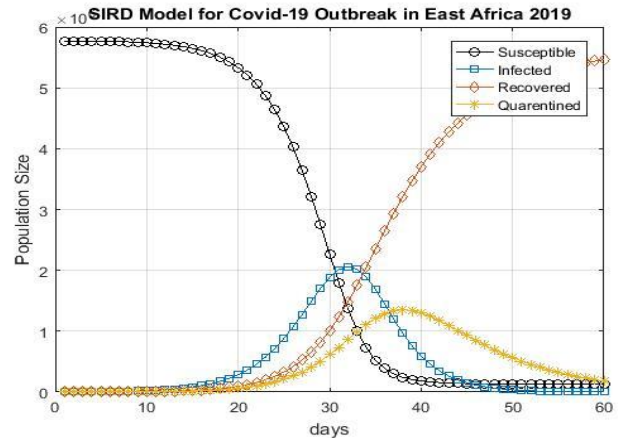


Figure 22 Simple SIRQ Quarantine

After taking vaccination simple SIRQ model without vaccination and applied 10 % of the infective Population for the population of quarantined we see the graph from the legend infected reduced. To know the impact of vaccination on the spread of the virus I have taken assumption that 1% and 10% of the susceptible population is vaccinated just to illustrate the impact of vaccinated and the significant of it.

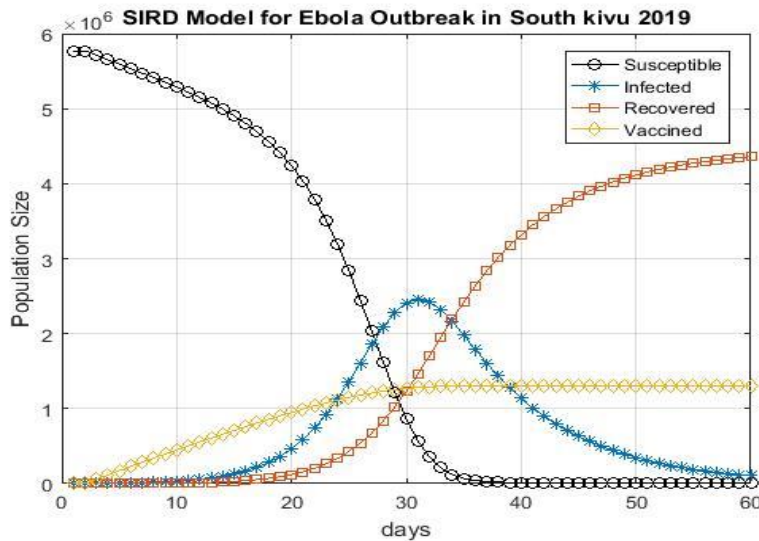


Figure 23 SIRD model for Ebola outbreak in South Kivu 2019

Figure 23 illustrates based on the data given below which is $S(1)=5768294$; Susceptible population, $I_n(1)=2859$; Infected people, $R(1)=847$; Recovered people, $D(1)=1902$; Death people, $\gamma=0.25$; $\beta=0.0015$; SIRD Model for Ebola Outbreak in DRC 2019.

4.14 Africa Map location of East Africa Coronavirus Report

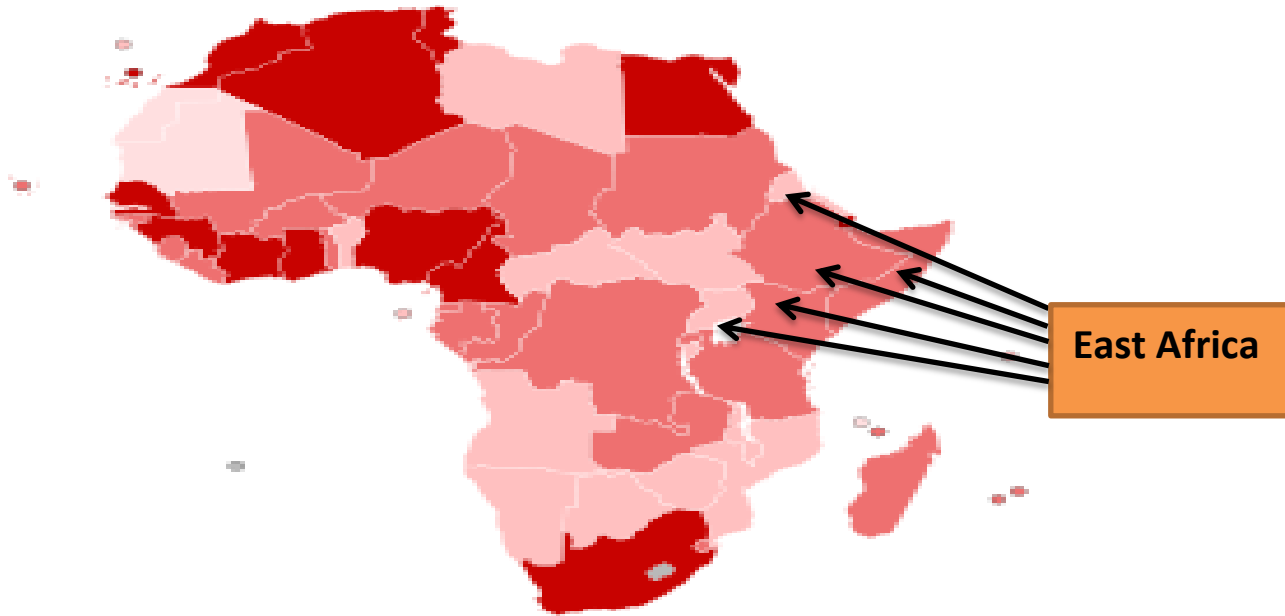







Figure 24 Covid-19 Virus Distribution Map: Cases of Covid-19 Virus in Africa.

In 1892 the first coronavirus arose, infectious was isolated by Fred Beaudette in 1937, followed by severe acute respiratory syndrome coronavirus SARS-COV in 2002 and Middle East respiratory syndrome coronavirus MERS-COV in 2012. Currently about 21000 deaths out of over 470000 cases with about 82000 reported by China and a total of over 380000 confirmed from 194 countries till the 25th March 2020 [18]. The difference between SARS-COV-2 and other coronaviruses Etiology and origin of SARS-CoV-2 which this paper summarized records of index cases in Africa, in addition to the preventive strategies Coronaviruses (COVs) are positively sensed single-stranded RNA viruses that belong to the order Nidovirales, family Coronaviridae, and subfamily ortho corona virinae with 4 genera: alpha, beta, delta, and gamma coronaviruses. Alpha COVs and beta COVs initiated from bats and rodents while delta COVs and gamma COVs have their origins from avian species [18]

In 1992 beta COVs SARS-COV-1 was isolated from bats being the intermediary host; MERS-COV was isolated from dromedary camels in 2003 and of course the currently circulating SARS-CoV-2 formally referred to as 2019 novel coronavirus causing COVID-19. With symptomatic people being it can be transmitted from

human-to-human by respiratory droplets from sneezing, and coughing. With the major source of transmission it has a dynamic incubation period of about 7 to 14 days. similarity to a bat SARS-related coronavirus isolated in China against < 80% to the genomes of SARS-COV and < 50% to MERS-COV according to Lu et al; Zhou et al. which further confirmed the similarity between the novel virus and bat beta corona virus in the sub-genus Asian [19].

Table 2 Summary table of Covid-19 confirmed cases in Africa (as of 9 May 2020)

Location	Confirmed cases	Active confirmed cases	Recoveries	Deaths
 Ethiopia	194	95	95	4
 Eritrea	39	30	9	0
 Kenya	621	390	202	29
 Uganda	114	59	55	0
 Djibouti	1,135	308	824	2

Report for the month of May 9, 2020

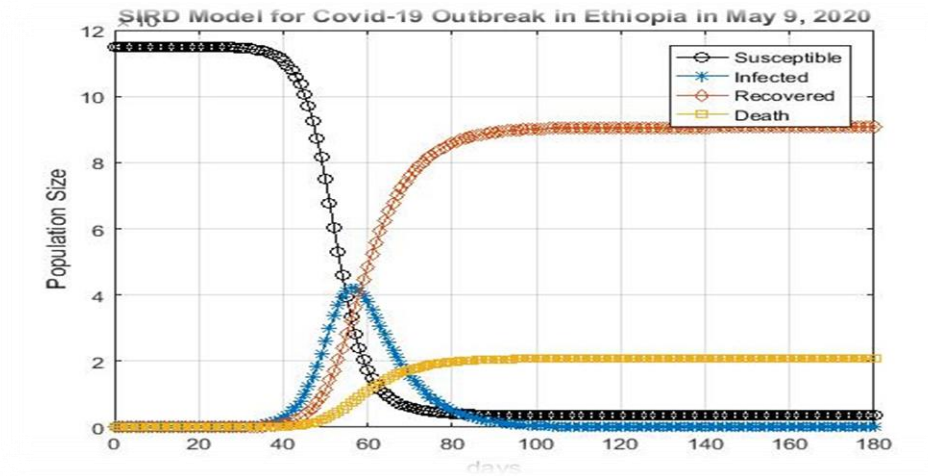



Figure 25 Data of Ethiopia during Pandemic Covid-19

Location	Confirmed cases	Active case confirmed	Recoveries	Deaths
 Ethiopia	194	95	95	4

We know that the population of Ethiopia currently is 114,963,588 as of Saturday, May 9, 2020 based on world meter elaboration of the latest United Nations data. Ethiopia 2020 population is estimated at 114,963,588 people whom we see on the graph population of Ethiopia which start from 114 million midyear according to UN data. So far Covid-19 cases are 95 infected on May 9, 2020, recovered 95 May 9, 2020 deaths are 4 recorded on May 9, 2020. So we see the graph the population it illustrate Susceptible and the color illustrate infected people very much less than the susceptible and death is the death color which is only four people for the month of May 9, 2020.

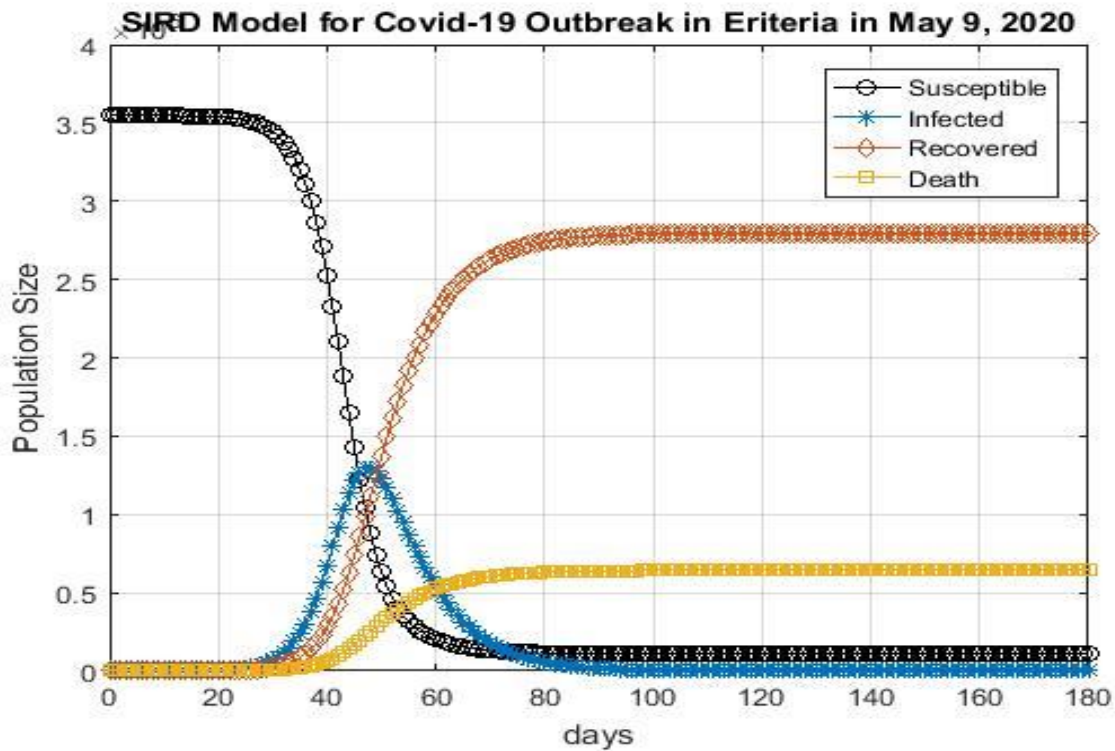



Figure 26 data of Eritrea during Pandemic Covid-19 May 9, 2020

Location	population	Confirmed cases	Active case confirmed	Recoveries	Deaths
 Eritrea	3,546,421	39	30	9	0

When we compare the population of Eritrea is four times less than Ethiopia so we see the death is zero infected 30 and recovered one is 9 and death 0 on May 9, 2020. The population of Eritrea is 3,546,421 which we see the population indicates the population which begins from three million five hundred and we see the graph as the recovering people increases the number of people death is becoming zero.

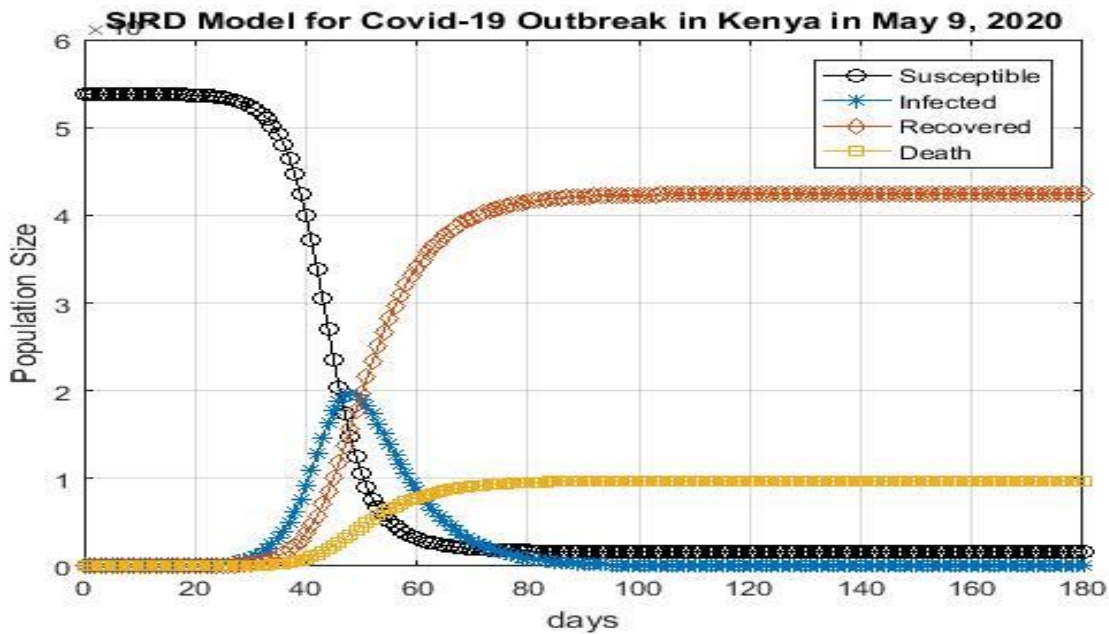



Figure 27.data of Kenya during Pandemic Covid-19 May 9, 2020

Location	Population	Confirmed case	Active case	Recoveries	Death
 Kenya	53,771,296	621	390	202	29

We know that the population of Kenya currently is 53,771,296 as of Saturday, May 9, 2020 based on world meter elaboration of the latest United Nations data. Kenya 2020 population is estimated at 53,771,296 People which indicates or illustrates on the graph with the black color mid-year according to UN data. So far Covid-19 cases are 390 infected which illustrates by blue color recovered 202 deaths are 29. So we see the graph

population Susceptible the whole the black color people and infected the blue color very much less than the susceptible and death is the yellowish color which is only twenty nine people for the month of May 9, 2020. compare to others data on the graph the death is very low data as we see the numeric data as well as on the graph. But overall data the highest data is the susceptible and the graph also indicating us the overall population or susceptible one is the highest figure on the graph.

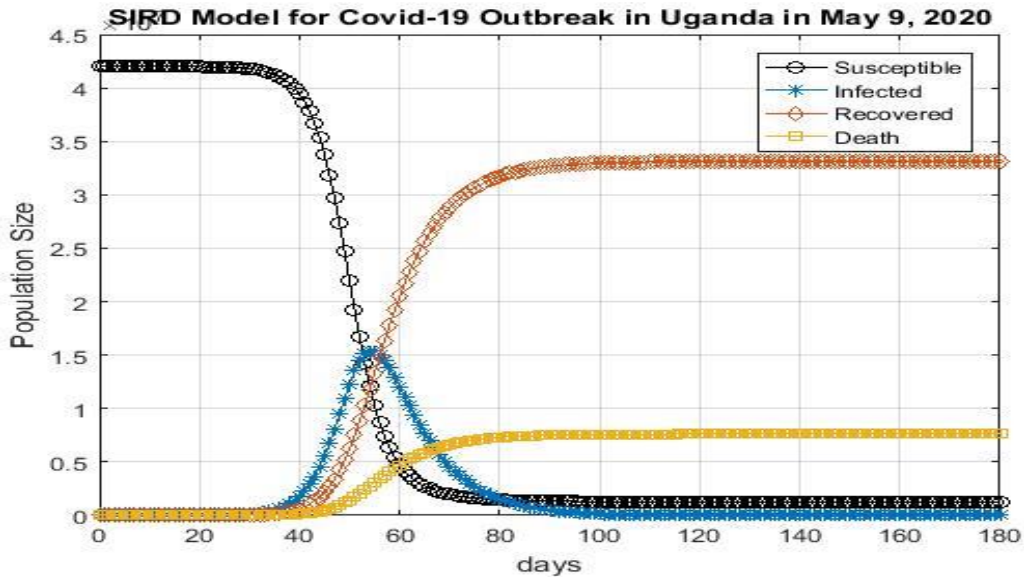



Figure 28 Data of Uganda country during Pandemic Covid-19 May 9, 2020

Location	Population	Confirmed case	Active case	Recoveries	Death
 Uganda	42,000,072	114	59	55	0

We know that the population of Uganda currently is 42,000,072 as of Saturday, May 9, 2020 based on world meter elaboration of the latest United Nations data. Kenya 2020 population is estimated at 42,000,072 People midyear according to UN data. So far Covid-19 cases are 59 infected recovered 55 deaths are 0. So we see the graph population Susceptible the whole the black color people and infected the blue color very much less than the susceptible and death is the yellowish color which is zero people for the month of May 9, 2020.

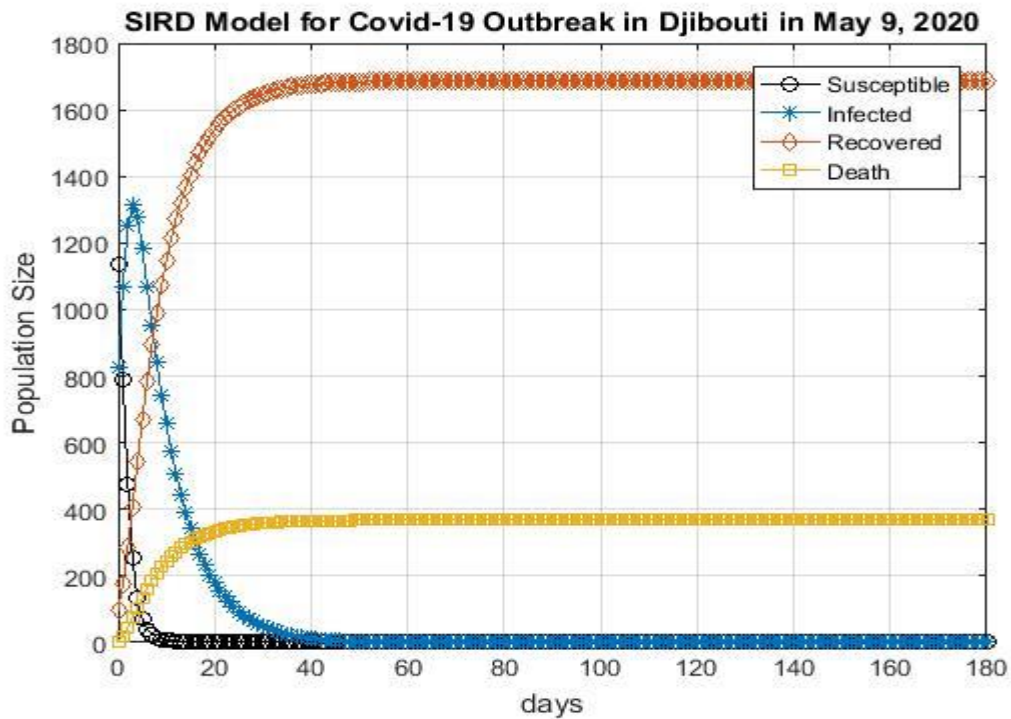



Figure 29 Data for Djibouti country during Pandemic Covid-19 May 9, 2020

Location	Population	Confirmed case	Active case	Recovered	Deaths
 Djibouti	942,208	1,135	308	824	2

Know that the population of Djibouti currently is 1,135 as of Saturday, May 9, 2020 based on world meter elaboration of the latest United Nations data. Kenya 2020 population is estimated at 1135 People midyear according to UN data. So far Covid-19 cases are 308 infected recovered 2 deaths. So we see the graph population Susceptible the whole the black color people and infected the blue color very much less than the susceptible and death is the yellowish color which starts 2 people for the month of May 9, 2020.

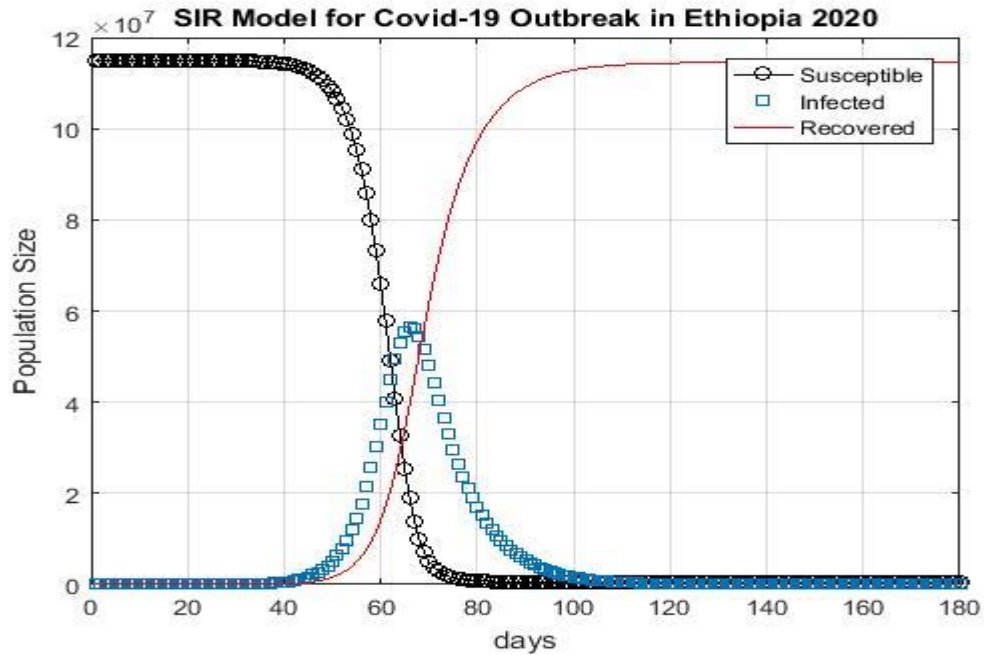



Figure 30 SIR data of Ethiopia during pandemic May 9, 2020

Location	population	Confirmed case	Active case	Recoveries	Deaths
 Ethiopia	114,963,588	194	95	95	5

The above graph describes simple SIR model through Mat lab which is design to easily plot the graph by giving the numeric data which is given from any institution. For example the above Data is given by the Ethiopia Ministry of health with the population of 114,963,588, with initial infection value of 95, initial recovery of 99 and the rates are infectious rate is 0.42 & recovery rate is 0.1. So we see the above graph simple SIR model through Mat lab easily we can identify by giving the data of any country Matlab.

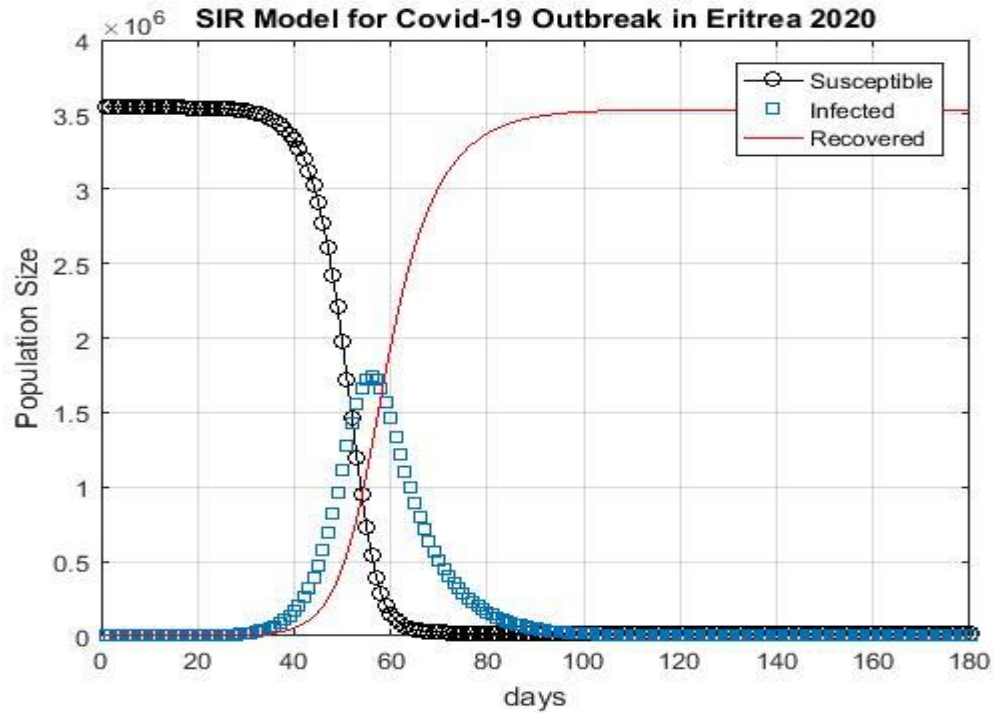



Figure 31 SIR data of Eritrea during pandemic May 9, 2020

Location	Population	Confirmed case	Active case	Recoveries	deaths
 Eritrea	3,546,421	39	30	9	0

The above graph is a Simple SIR Model plotted through Matlab which has the population of Eritrea Susceptible = 2,546,421, infected 30 people and recovery = 9 with infectious rate or probability of the person being infected = 0.42 is given and recovery Rate is = 0.1. By computing the numeric data the application describes the graph how the data behaves. So the above graph Clearly indicates how the people of Eritrea reacting through this pandemic era and we see the number of people with the 30 infected people and nine people recovered with zero death.

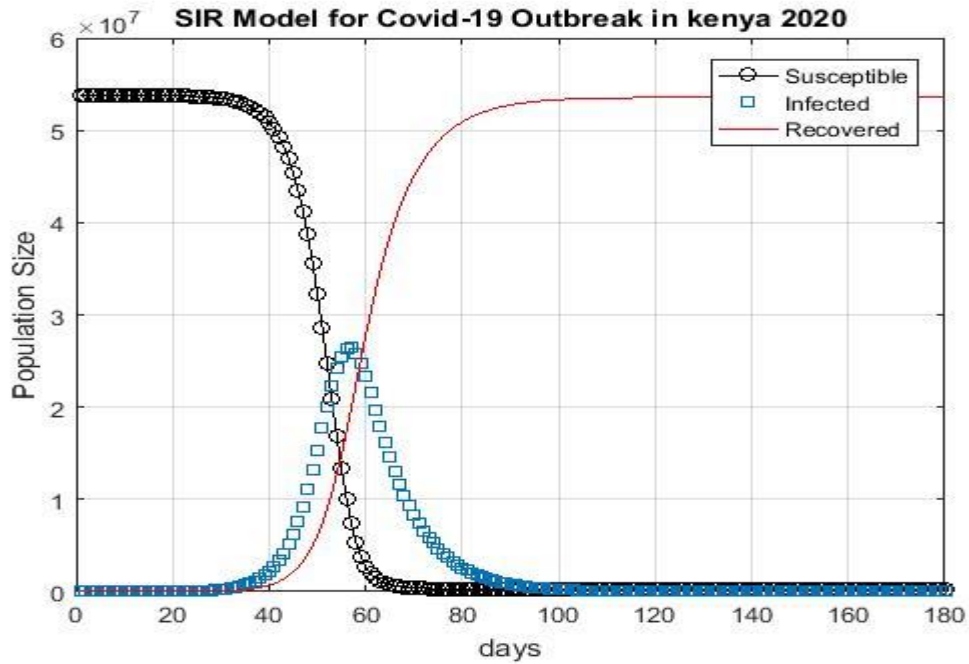



Figure 32 SIR data of Kenya during pandemic May 9, 2020

Location	Population	Confirmed case	Active case	Recoveries	Deaths
 Kenya	53771296	621	390	202	29

The above graph is a Simple SIR Model plotted through Matlab which has the population of Kenya Susceptible = 53,771,296, infected 390 people and recovery = 230 with infectious rate or probability of the person being infected = 0.42 is given and recovery Rate is = 0.1.

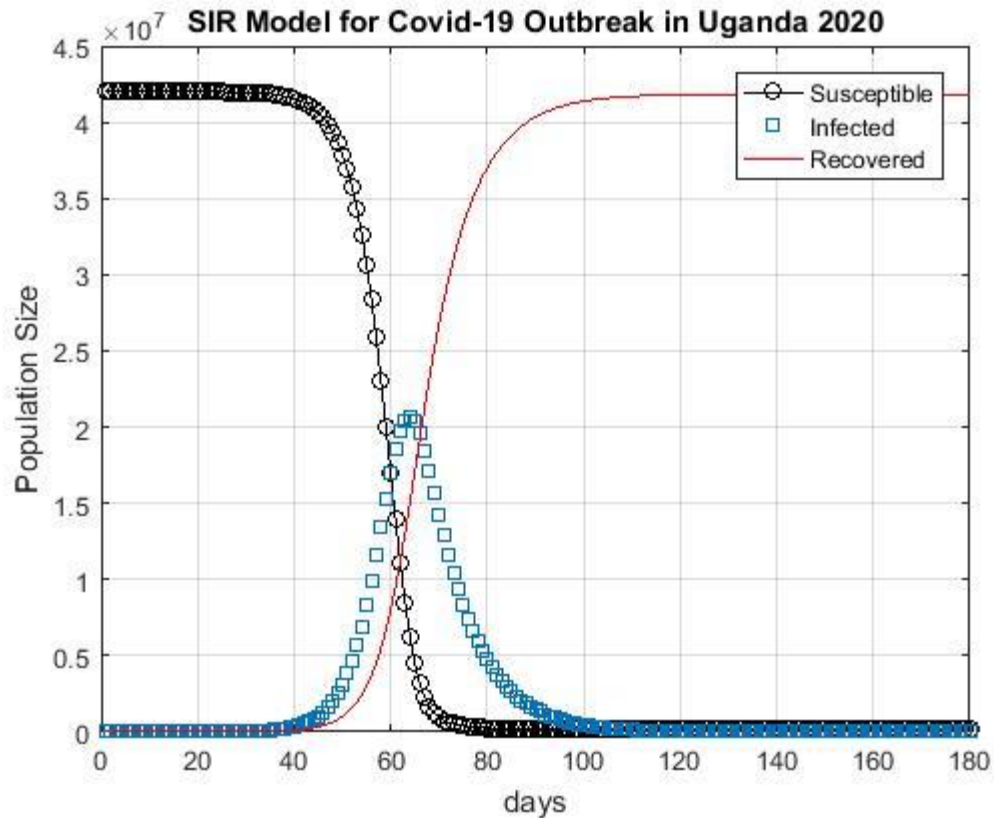



Figure 33. Data of Uganda during pandemic May 9, 2020

Location	Population	Confirmed case	Active cases	Recoveries	Deaths
 Uganda	42,000,072	114	59	55	0

The above graph is a Simple SIR Model plotted through Matlab which has the population of Uganda Susceptible = 42,000,072, infected 59 people and recovery = 55 with infectious rate or probability of the person being infected = 0.42 is given and recovery Rate is = 0.1. By computing the numeric data the application describes the graph how the data behaves. So the above graph Clearly indicates how the people of Uganda reacting through this pandemic era and we see the number of people with the 59 infected people and fifty five people recovered. You see after infections we see the population decline and after immunity developed by its own time we see the recovery inline up after immunity developed.

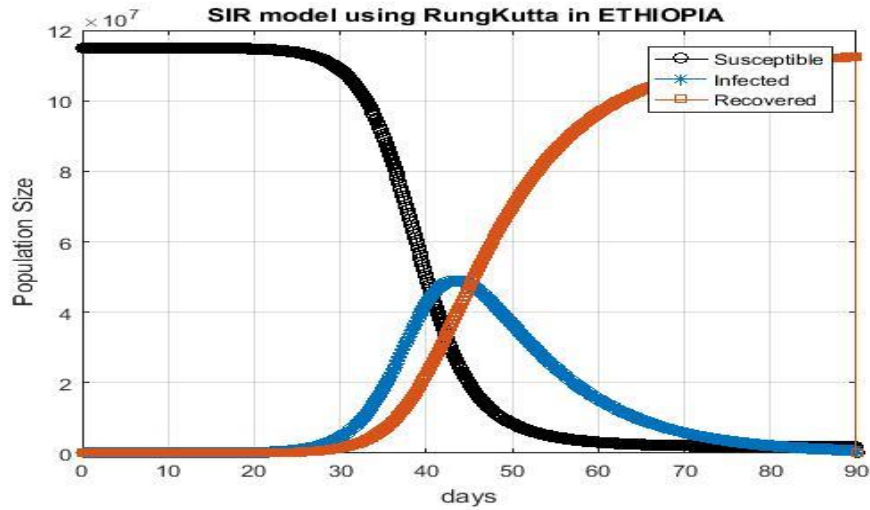


Figure 34 The graph Ethiopia through Rung kutta matlab code

This program was written to investigate the spreading of Covid-19 at the mentioned and the reasoning for the specific choices β 0.000000163 and 0.1 goes as follows. At some other place where the disease has already spread, it was observed that in the beginning of a day there were initially 114963588 susceptible, 60 days. This program was written to investigate the spreading of Covid-19 at the mentioned Ethiopia and the reasoning for the specific choices β and γ goes as follows. At some other place where the disease has already spread, it was observed that in the beginning of a day there were initially 114963588 susceptible, 60 days.

From the graph you can see that the red color is susceptible people over 114963588 and the green color is infected people where as the blue color is Recovered people.

- $N = 114963588$
- $I = 95$
- $R = 95$
- Died = 4

Therefore, $S = N - I + R = 114963588 - (95 + 95) = 114963398$

- The duration of the virus ranges from 1 to 14 days, therefore we could roughly estimate the duration of the disease at the midpoint, i.e. 7 days.
- $D = 7$
- $Y = 1/7 = 0.1$

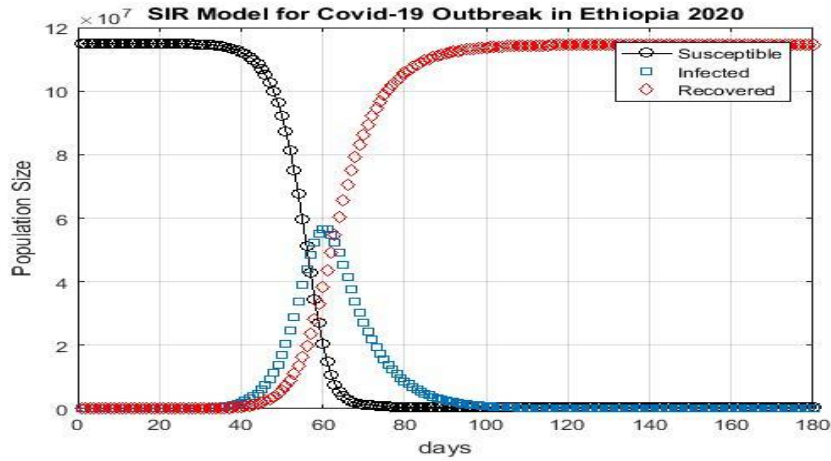


Figure 35 Simple SIR Model without trail vaccination Covid-19

Simple SIR Model without trail vaccination

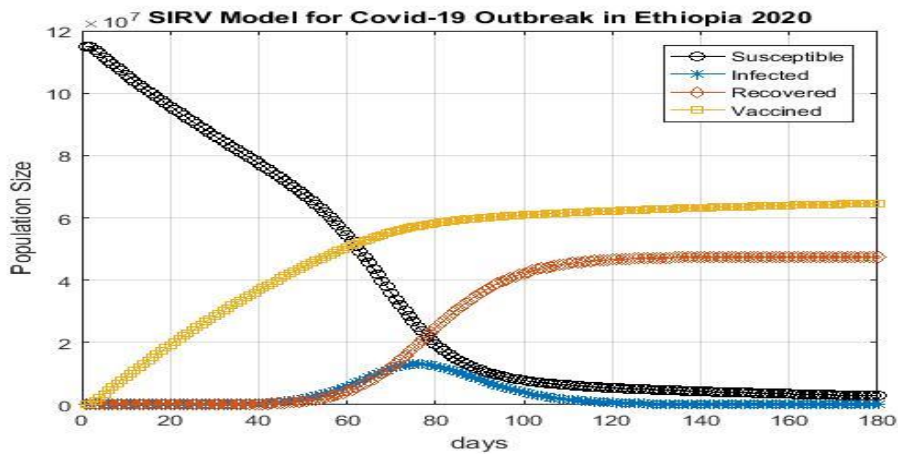


Figure 36 Comparison between SIR without and SIR with trail Vaccination

Simple SIRV with vaccination applied to one percent of the susceptible population on figure 45A explains that the infected rate is high because it is without vaccination so we see the infected color which indicate that the graph is high where us the figure 46B. Indicates with vaccination infected color the infected rate is down by one thousand numbers.

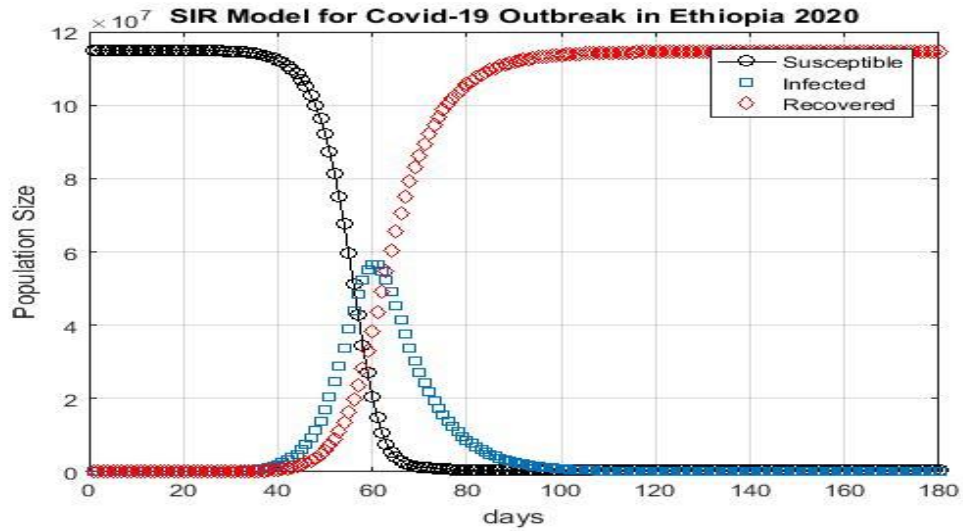


Figure 37 Simple SIR Model without trail vaccination is the population over 114 million people.

$s(1)=114,963,588$; $in(1)=352$; $r(1)=116$; $G=0.1$; $B=0.42/114963588$; $dt=1$; % given; given values for Susceptible, Infected, recovered, gama and Bata. The above graph explains the comparison between SIR and SIRV. Meaning when there is no vaccine and when there is vaccine.

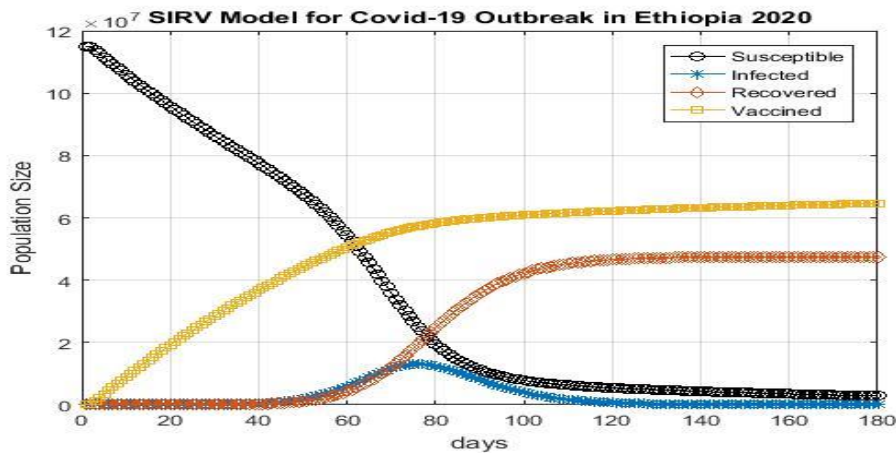


Figure 38 Simple SIRV model with vaccination

Applied to 1% of the susceptible population after the susceptible people took vaccination the number reduced by 1 million people so the blue color clearly illustrates the reduced number of the people. $s(1)=114963588$; $in(1)=352$; $r(1)=116$; $G=0.1$; $B=0.42/114963588$; $dt=1$; $v(1)=0$; given % values for Susceptible, Infected, recovered, Vaccine = 0gama and Bata.

Comparison between SIR and Vaccination on trial

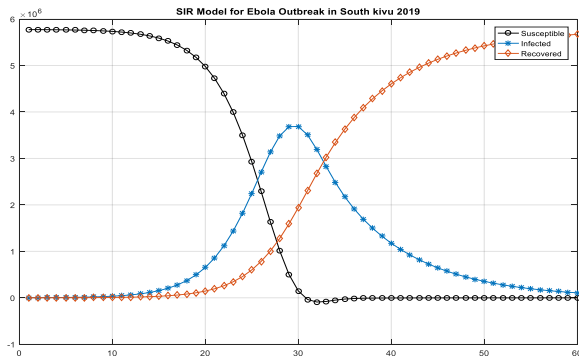


Figure 39 Simple SIR Model

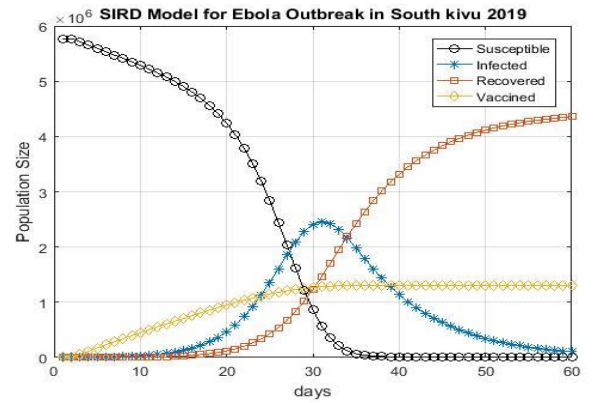


Figure 40 Vaccinations on trial

SIRV 10 % of infective population Simple model for the population without vaccination applied to after taking vaccination of quarantined. We see the graph from the legend infected reduced.

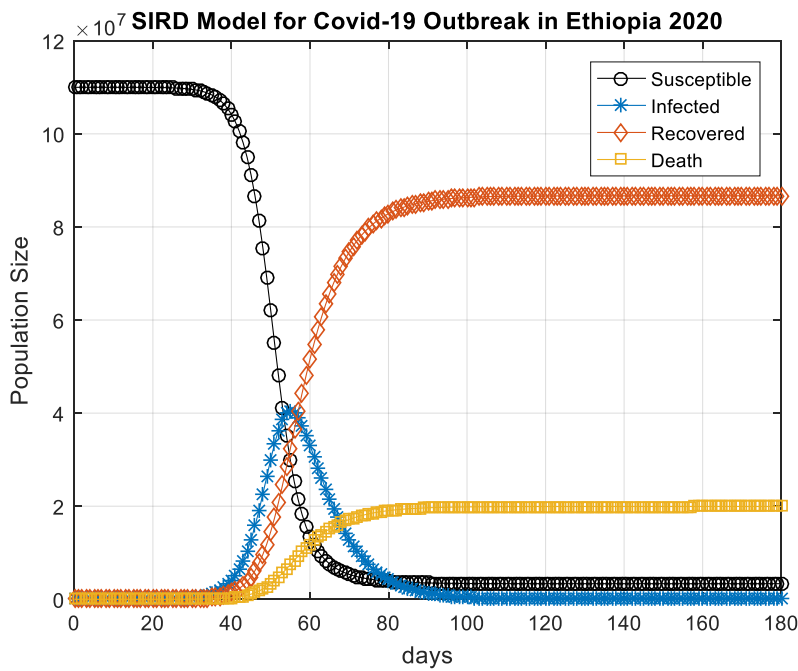


Figure 41 SIRD model for Covid-19 outbreak in Ethiopia 2020

The above graph illustrates based on the data given below which is $S(1)=5,768,294$; Susceptible population, $I(1)=2,859$ with the blue color; Infected people, $R(1)=847$; Recovered people, $D(1)=1902$ with square yellow color Death people, $\gamma=0.25$; $\beta=0.0015$; SIRD Model for Covid-19 Outbreak in ETHIOPIA 2020.

Chapter 5 Application of SIR model on Collected Data

5.1. Running the SIR model on the first values numbers of the Ebola Epidemic in Liberia in 2014

Ebola outbreak in Liberia 2014, the total population of Liberia, and we can assign the parameters with the following values. $N = 4294000$, the number of people infected ($I = 846$) and the number of people dead is 481. The number of people who have received perpetual protection seeing as R includes, this includes those who have died as they have enduring protection, in addition to those who have recovered with enduring immunity.

$$\text{Number of people recovered } R = 481 + (0.3 \times 846) = 735$$

$$N = 4294000$$

$$I = 846$$

$$R = 735$$

$$S = N - I + R = 4294000 - (735 + 846) = 4292419$$

Then we could roughly approximation and the historical of the disease ranges from 2 to 18 days, thus we could unevenly approximately the period of the disease at the midpoint, i.e., 10 days.

$$D = 10$$

$$\gamma = \frac{1}{10} = 0.1$$

The mortality rate of Ebola is 0.7^{th} and the number of people susceptible is 4292419,

Equation 5,

$$(\text{the rate of infection}) = \frac{0.7}{4292419} = 1.63 \times 10^{-7}$$

The SIR model in order predicts the evolution of the disease, and it would be helpful if we could solve the system of differential equations which we cannot completely solve these equations with an explicit formula solution.

Then , I will use a numerical method, as follows , For each day, I will calculate the values of $\frac{ds}{dt}$, $\frac{dI}{dt}$ and $\frac{dR}{dt}$

I will do this explicitly for the transition from $t = 1$. And the following values for the three rates of change of S, I and R can be calculated.

$$\frac{ds}{dt}_{t=0} = (-1.63 \times 10^{-7}) \times 846 \times 4292419 = -581$$

$$\frac{ds}{dt}_{t=0} = (1.6 \times 10^{-7}) - (0.1 \times 846) = 496$$

Thus, at $t = 1$,

$$S = 4292419 - 581 = 4291838$$

I will now uses excel to do this over a two month period, by putting in the methods in the following technique. I well-defined γ in as g in cell I1 and β as b in cell J3:

Table 3 sixty days of the SIR model also shows the change in rate of each day of the sixty days data including the entire graph

T	S	I	R	dS/dt	dI/dt	dR/dt	S+I+R	gamma	Beta
0	4292419	846	735	-581	496	85	4294000	0.1	1.60E-07
1	4291838	1342	820	-922	788	134	4294000	0.1	1.60E-07
2	4290916	2130	954	-1462	1249	213	4294000	0.1	1.60E-07
3	4289454	3379	1167	-2319	1981	338	4294000	0.1	1.60E-07
4	4287134	5361	1505	-3677	3141	536	4294000	0.1	1.60E-07
5	4283457	8502	2041	-5827	4977	850	4294000	0.1	1.60E-07
6	4277631	13478	2891	-9225	7877	1348	4294000	0.1	1.60E-07
7	4268406	21355	4239	-14585	12449	2136	4294000	0.1	1.60E-07
8	4253821	33804	6374	-23008	19627	3380	4294000	0.1	1.60E-07
9	4230814	53432	9755	-36169	30826	5343	4294000	0.1	1.60E-07
10	4194644	84258	15098	-56549	48123	8426	4294000	0.1	1.60E-07
11	4138095	132381	23524	-87649	74411	13238	4294000	0.1	1.60E-07
12	4050446	206792	36762	-134016	113337	20679	4294000	0.1	1.60E-07
13	3916430	320129	57441	-200602	168589	32013	4294000	0.1	1.60E-07
14	3715828	488718	89454	-290559	241687	48872	4294000	0.1	1.60E-07
15	3425269	730405	138326	-400294	327253	73041	4294000	0.1	1.60E-07
16	3024975	1057658	211366	-511902	406137	105766	4294000	0.1	1.60E-07
17	2513073	1463795	317132	-588580	442200	146379	4294000	0.1	1.60E-07
18	1924493	1905995	463512	-586892	396292	190600	4294000	0.1	1.60E-07
19	1337601	2302288	654111	-492727	262498	230229	4294000	0.1	1.60E-07
20	844874	2564786	884340	-346707	90229	256479	4294000	0.1	1.60E-07
21	498167	2655015	1140819	-211622	-53879	265501	4294000	0.1	1.60E-07
22	286544	2601136	1406320	-119255	-140859	260114	4294000	0.1	1.60E-07
23	167290	2460277	1666434	-65853	-180175	246028	4294000	0.1	1.60E-07
24	101437	2280102	1912461	-37006	-191004	228010	4294000	0.1	1.60E-07
25	64431	2089097	2140471	-21537	-187373	208910	4294000	0.1	1.60E-07

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26	42895	1901724	2349381	-13052	-177121	190172	4294000	0.1	1.60E-07
27	29843	1724604	2539554	-8235	-164226	172460	4294000	0.1	1.60E-07
28	21608	1560378	2712014	-5395	-150643	156038	4294000	0.1	1.60E-07
29	16213	1409735	2868052	-3657	-137316	140973	4294000	0.1	1.60E-07
30	12556	1272418	3009025	-2556	-124686	127242	4294000	0.1	1.60E-07
31	10000	1147733	3136267	-1836	-112937	114773	4294000	0.1	1.60E-07
32	8164	1034796	3251040	-1352	-102128	103480	4294000	0.1	1.60E-07
33	6812	932668	3354520	-1017	-92250	93267	4294000	0.1	1.60E-07
34	5796	840418	3447787	-779	-83262	84042	4294000	0.1	1.60E-07
35	5016	757155	3531828	-608	-75108	75716	4294000	0.1	1.60E-07
36	4409	682047	3607544	-481	-67724	68205	4294000	0.1	1.60E-07
37	3927	614324	3675749	-386	-61046	61432	4294000	0.1	1.60E-07
38	3541	553277	3737181	-313	-55014	55328	4294000	0.1	1.60E-07
39	3228	498263	3792509	-257	-49569	49826	4294000	0.1	1.60E-07
40	2971	448694	3842335	-213	-44656	44869	4294000	0.1	1.60E-07
41	2757	404038	3887205	-178	-40226	40404	4294000	0.1	1.60E-07
42	2579	363813	3927608	-150	-36231	36381	4294000	0.1	1.60E-07
43	2429	327581	3963990	-127	-32631	32758	4294000	0.1	1.60E-07
44	2302	294951	3996748	-109	-29386	29495	4294000	0.1	1.60E-07
45	2193	265564	4026243	-93	-26463	26556	4294000	0.1	1.60E-07
46	2100	239101	4052799	-80	-23830	23910	4294000	0.1	1.60E-07
47	2019	215271	4076709	-70	-21458	21527	4294000	0.1	1.60E-07
48	1950	193814	4098236	-60	-19321	19381	4294000	0.1	1.60E-07
49	1889	174493	4117618	-53	-17397	17449	4294000	0.1	1.60E-07
50	1837	157096	4135067	-46	-15663	15710	4294000	0.1	1.60E-07
51	1791	141433	4150777	-41	-14103	14143	4294000	0.1	1.60E-07
52	1750	127330	4164920	-36	-12697	12733	4294000	0.1	1.60E-07
53	1714	114633	4177653	-31	-11432	11463	4294000	0.1	1.60E-07
54	1683	103201	4189116	-28	-10292	10320	4294000	0.1	1.60E-07
55	1655	92909	4199436	-25	-9266	9291	4294000	0.1	1.60E-07

56	1631	83642	4208727	-22	-8342	8364	4294000	0.1	1.60E-07
57	1609	75300	4217091	-19	-7511	7530	4294000	0.1	1.60E-07
58	1589	67789	4224621	-17	-6762	6779	4294000	0.1	1.60E-07
59	1572	61028	4231400	-15	-6087	6103	4294000	0.1	1.60E-07
60	1557	54940	4237503	-14	-5480	5494	4294000	0.1	1.60E-07

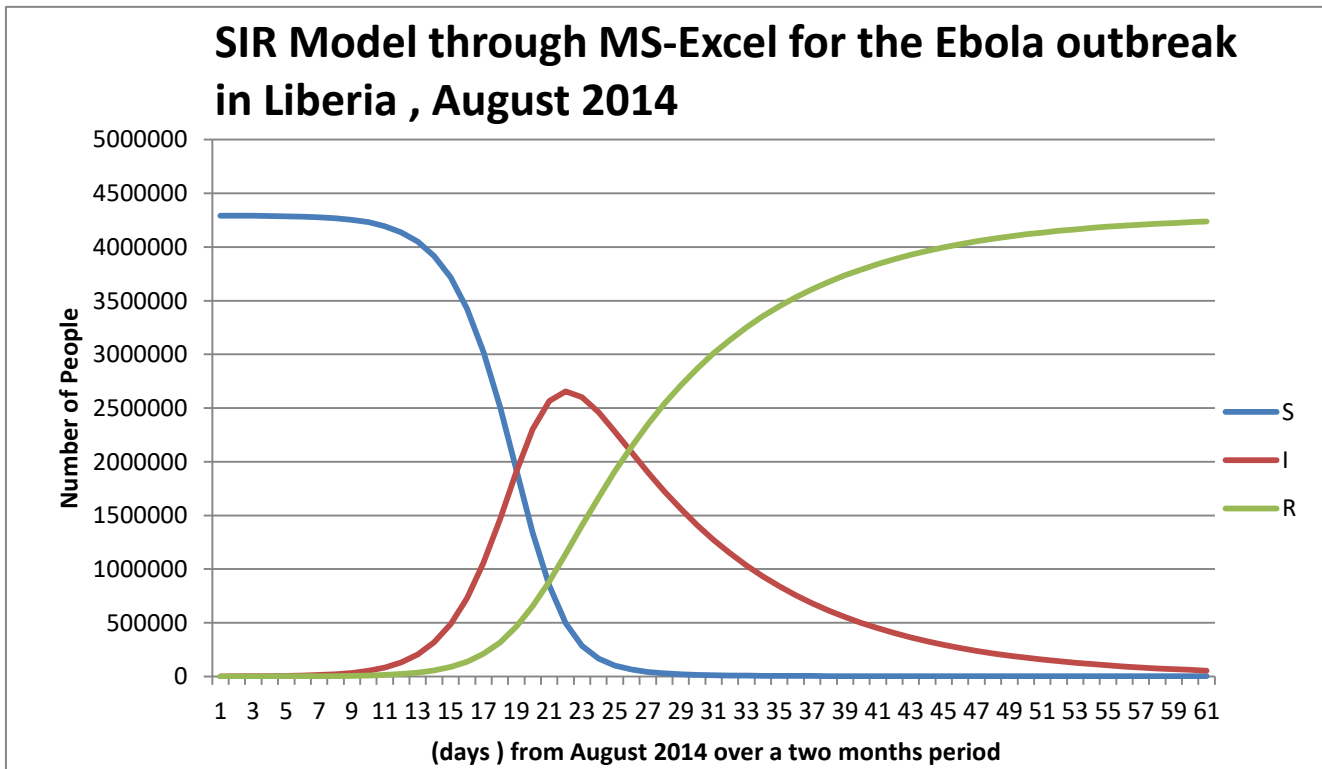


Figure 42 .MS-Excel plot of Ebola outbreak in Liberia in August 2014

Comparison between SIR model through MS-Excel Graph and SIR model through Matlab Graph of more than two months and the population of more than forty two million people. Susceptible, Infected and Recovered for the first 10 days From the above picture we understand the activities of the number of people susceptible to the disease leftovers continuous, and then it suddenly decrease to create a negative sigmoidal curve. In reverse this means that it is shaped like the letter S, and it must be notice the number of people never reaches zero, and only inclines near it allowing the epidemic to reoccur in the upcoming. The only way for the number of susceptible to reach approximate value which will be near to the x line is through the vaccination as this acts as a vehicle to remove the disease from the population.

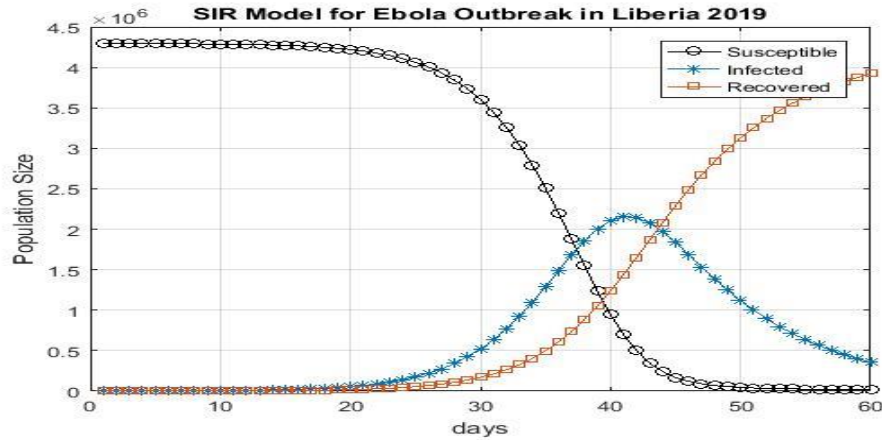


Figure 43 . The graph of Ebola outbreak of sixty days in Liberia through Mat lab code August 2014.

We see the similarity of the graph both MS-Excel and Mat lab coding. The above graph explains that if we now take the example of the Ebola outbreak in Liberia 2014, we can assign the parameters with the following values. The total population of Liberia, $N = 4294000$ which you see the black circle on the legend, and according to data from WHO, the number of people infected $I = 846$ which we see the blue star on the graph and the number of people recovered is $R = 735$. Seeing as R on the legend and the square sign on the graph, includes the number of people who have received permanent immunity, permanent immunity this includes those who have died as they have, in addition to those who have recovered with permanent immunity. In general we put SIR model with parameter as follows $S(1) = 4294000$; $I(1) = 846$; $R(1) = 735$; $\gamma = 0.1$; $\beta = 0.000000163$; $dt = 1$ SIR Model for the Ebola outbreak in Liberia August 2014. The Susceptible figure shows that the population of Liberia is 4294000 indicated in the legend by the symbol of black circle it starts from number of days one up to sixty days and the infected 846 population indicated in the legend by the blue star color and recovered people 735 indicated by brown square color. So when we compare both graph MS-Excel and Mat lab code the initial values clearly illustrates the similarity of SIR model.

To actual figures trying to improve it comparing the model, the figure below compares the data collected from the model for the number of people infected and the real life data of the number of people infected. From this I can plot a graph using mat-lab code.

The number of people infected increases steeply as expected; this shows that initially, however, over a longer period of time, the numbers eventually decrease. This happens as the number of people recovered increases simultaneously because as those infected decreases, they are being transferred into the recovered category.

The main reason is due to the increased awareness of the diseases leading to further medical support being given in order to help combat the transmission of the diseases. Ebola letting a greater rate of transmission additionally, an increased consciousness results in more people being conscious of approaches of protection, the vertical increase in the beginning of the first 15 days is most likely to be due to the great uncertainty that lied with. There is a transition whereby the number decrease. Graph illustrates the peak of maximum number of people ever to be infected and after this point;

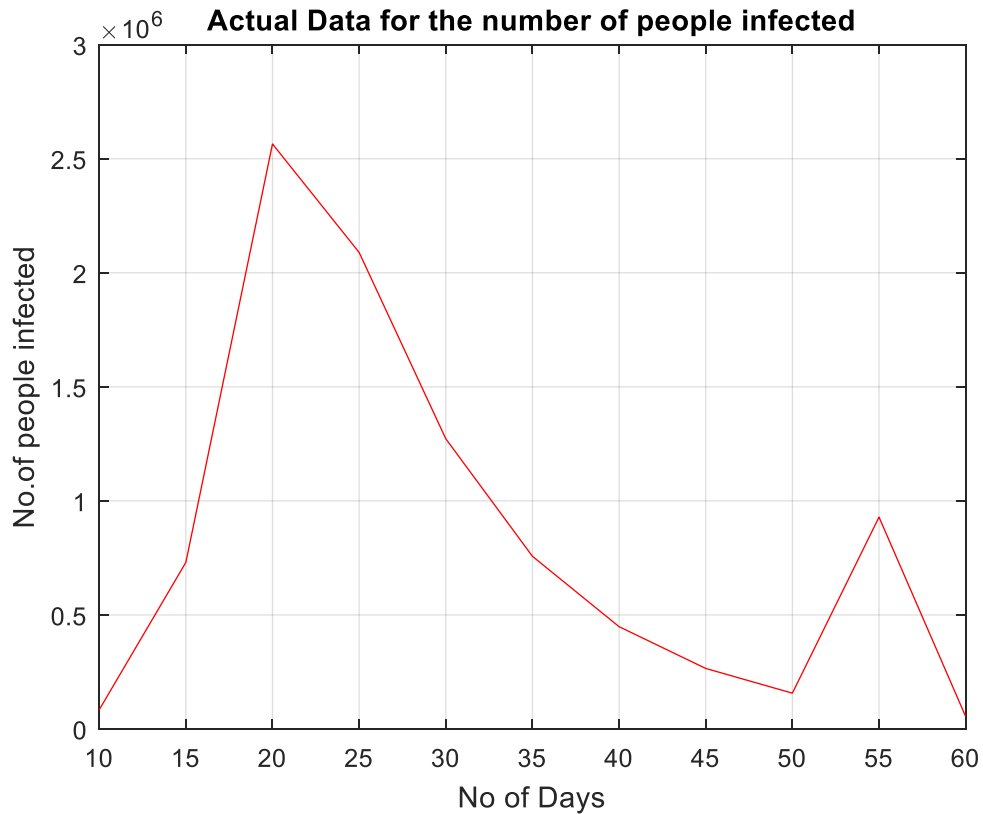


Figure 44 Gathered data and data analysis on mat lab code

5.1.1. Polynomials

Table 4 Tabular Data Points collected from the given problem

Days or time	Actual data	Confirmed Cases
✓ 10	84,258	1,378
15	730,405	1,680
20	2,564,786	1,871
✓ 25	2,089,097	2,046
30	1,272,418	2,407
35	757,155	3,022
40	448,694	3,280
✓ 45	265,564	3,696
50	157,096	3,834
55	92,909	4,076
✓ 60	54,940	4,262

$$x_0 = 10, \quad x_1 = 25, \quad x_2 = 45, \quad x_3 = 60$$

$$f(x_0) = 1378, \quad f(x_1) = 2046, \quad f(x_2) = 3696, \quad f(x_3) = 4262$$

$$I(x) = \sum_{i=0}^3 L_i(x) \cdot f(x_i)$$

5.1.1.1 Where Lagrange coefficient polynomials

$$L_i(x) = \prod_{\substack{j=0 \\ j \neq i}}^3 \frac{x - x_j}{x_i - x_j},$$

Note that in the Lagrange coefficient $\mathbf{j \neq i}$, so we lock the \mathbf{j} in a box not to use at $\mathbf{j = i}$. Lagrange coefficient polynomial at $x = 10$ becomes:

$i = 0, \mathbf{j} \neq 0$, that means $j = 1, 2, 3$

$$L_0(x) = \frac{(x-x_1)(x-x_2)(x-x_3)}{(x_0-x_1)(x_0-x_2)(x_0-x_3)} = \frac{(x-25)(x-45)(x-60)}{(1-25)(1-45)(1-60)}$$

$$= \frac{(6-25)(6-45)(6-60)}{(1-25)(1-45)(1-60)} = 0.064$$

$i = 1, \mathbf{j} \neq 1$, that means $j = 0, 2, 3$

$$L_1(x) = \frac{(x-x_0)(x-x_2)(x-x_3)}{(x_1-x_0)(x_1-x_2)(x_1-x_3)} = \frac{(x-25)(x-45)(x-60)}{(3-25)(3-45)(3-60)}$$

$$= \frac{(6-25)(6-45)(6-60)}{(3-25)(3-45)(3-60)} = 0.997$$

$i = 2, \mathbf{j} \neq 2$, that means $j = 0, 1, 3$

$$L_1(x) = \frac{(x-x_0)(x-x_1)(x-x_3)}{(x_2-x_0)(x_2-x_1)(x_2-x_3)} = \frac{(x-1)(x-3)(x-7)}{(5-1)(5-3)(5-7)}$$

$$= \frac{(6-10)(6-25)(6-60)}{(5-10)(5-25)(5-60)} = 0.746$$

$i = 3, \mathbf{j} \neq 3$, that means $j = 0, 1, 2$

$$L_1(x) = \frac{(x-x_0)(x-x_1)(x-x_2)}{(x_3-x_0)(x_3-x_1)(x_3-x_2)} = \frac{(x-10)(x-25)(x-45)}{(60-10)(60-25)(60-45)}$$

$$= \frac{(6-10)(6-25)(6-45)}{(60-10)(60-3)(60-45)} = -0.069$$

5.1.1.2 The Lagrange interpolating polynomial

The Lagrange interpolating polynomial for the question becomes as follows:-

$$I(x) = L_0(x).f(x_0) + L_1(x).f(x_1) + L_2(x).f(x_2) + L_3(x).f(x_3)$$

Where, $x_0 = 10, x_1 = 25, x_2 = 45, x_3 = 60$
 $f(x_0) = 1378, f(x_1) = 2046, f(x_2) = 3696, f(x_3) = 4262$

Therefore $I(x) = (0.064) x 1378 + (0.997) x 2046 + (0.746) x 3696 + (-0.069) x (4262)$

$$I(55) = 4,590.98$$

Our interpolation polynomial has given by:

$$f_3(x) = 2.83x^3 - 86.24x^2 + 355.75x - 7068.50 \tag{Eq. (1.20)}$$

So now we compute approximation of the derivative at $x=6$ with $h = 0.1$ and, $f(6) = 316.4994$,

$$f'(6) = 284.7 \text{ and } f(5) = 255.6834$$

5.1.1.3 Curve Fitting (Lagrange)

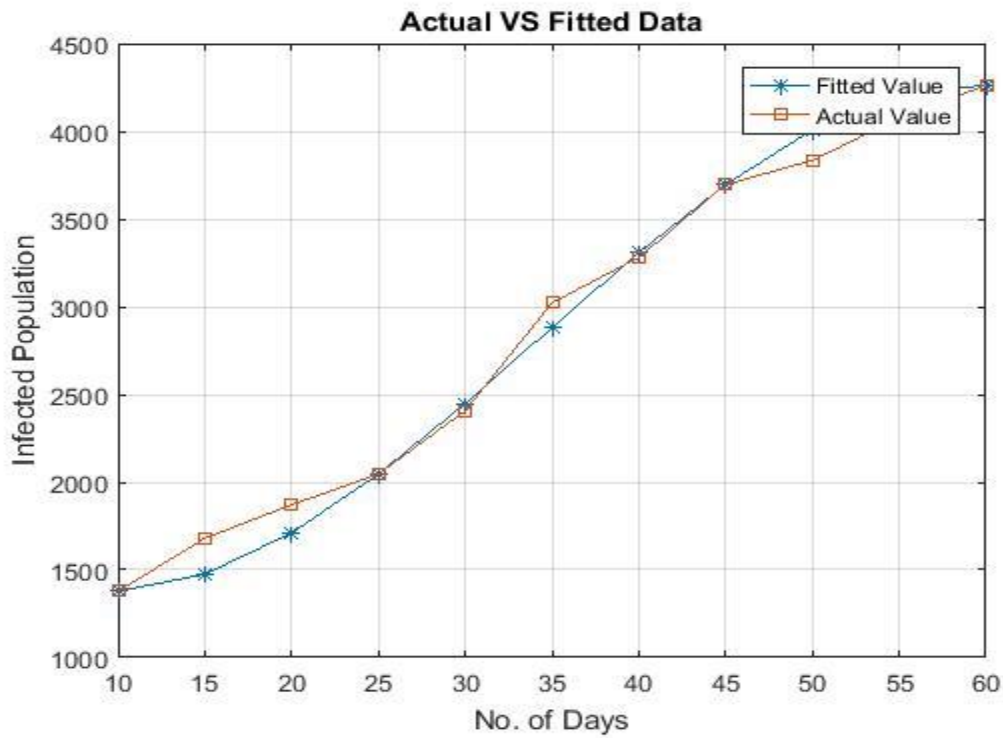


Figure 45. Actual Data versus fitted data.

Table 5 Data on the sixty days Tabular Data on the sixty days on the given data

No. of Days	Year(G.C)	Confirmed Cases
10	84258	1378
15	730405	1680
20	2564786	1871
25	2089097	2046
30	1272418	2407
35	757155	3022
40	448694	3280
45	265564	3696
50	157096	3834
55	92909	4076
60	54940	4262

5.1.1.4 Polynomial interpolation

Using Equation (1) a polynomial it involves the $n + 1$ points finding of order n that passes through $n + 1$, and we can solve the given question of order three polynomials the points are:-

$$x_0 = 10, \quad x_1 = 25, \quad x_2 = 45, \quad x_3 = 60$$

$$f(x_0) = 1378, \quad f(x_1) = 2046, \quad f(x_2) = 3696, \quad f(x_3) = 4262$$

5.1.1.5 The Newton’s interpolating polynomial become:-

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2)$$

$$b_0 = f(x_0) = 1378$$

$$b_1 = f[x_1, x_0] = \frac{f(x_1) - f(x_0)}{x_1 - x_0} = \frac{2046 - 1378}{25 - 10} = 133.60$$

$$b_2 = f[x_2, x_1, x_0] = \frac{\frac{f(x_2) - f(x_1)}{x_2 - x_1} - \frac{f(x_1) - f(x_0)}{x_1 - x_0}}{x_2 - x_0} = \frac{\left(\frac{3696 - 2046}{45 - 25}\right) - \left(\frac{2046 - 1378}{25 - 10}\right)}{45 - 10} = 140.16$$

$$b_3 = f[x_3, x_2, x_1, x_0] = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0}$$

$$f[x_3, x_2, x_1] = \frac{\frac{f(x_3) - f(x_2)}{x_3 - x_2} - \frac{f(x_2) - f(x_1)}{x_2 - x_1}}{x_3 - x_1} = \frac{\left(\frac{4262 - 3696}{60 - 45}\right) - \left(\frac{3696 - 2046}{45 - 25}\right)}{60 - 25} = -1.33$$

$$b_3 = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0} = \frac{-1.33 - (140.16)}{60 - 10} = 2.83$$

5.1.1.6 Third Order Finite Divided Differences for a given Function f(x)

The third order Newton is interpolating polynomial becomes

$$f_3(x) = 1378 + 133.60(x - 10) + 140.16(x - 10)(x - 25) + 2.83(x - 10)(x - 25)(x - 45)$$

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2)$$

A polynomial order n that passes through the n+1 points. Using Equation (1), we can solve the given question of order three polynomials interpolation involves finding the points are:-

$$\begin{aligned} x_0 &= 10, & x_1 &= 25, & x_2 &= 45, & x_3 &= 60 \\ f(x_0) &= 1378, & f(x_1) &= 2046, & f(x_2) &= 3696, & f(x_3) &= 4262 \end{aligned}$$

Then, The Newton's interpolating polynomial become:-

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2)$$

$$f_3(x) = 2.83x^3 - 86.24x^2 + 355.75x - 7068.50$$

$$b_1 = f[x_1, x_0] = \frac{f(x_1) - f(x_0)}{x_1 - x_0} = \frac{2046 - 1378}{25 - 10} = 133.60$$

$$b_2 = f[x_2, x_1, x_0] = \frac{\frac{f(x_2) - f(x_1)}{x_2 - x_1} - \frac{f(x_1) - f(x_0)}{x_1 - x_0}}{x_2 - x_0} = \frac{\left(\frac{3696 - 2046}{45 - 25}\right) - \left(\frac{2046 - 1378}{25 - 10}\right)}{45 - 10} = 140.16$$

$$b_3 = f[x_3, x_2, x_1, x_0] = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0}$$

$$f[x_3, x_2, x_1] = \frac{\frac{f(x_3) - f(x_2)}{x_3 - x_2} - \frac{f(x_2) - f(x_1)}{x_2 - x_1}}{x_3 - x_1} = \frac{\left(\frac{4262 - 3696}{60 - 45}\right) - \left(\frac{3696 - 2046}{45 - 25}\right)}{60 - 25} = -1.33$$

$$b_3 = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0} = \frac{-1.33 - (140.16)}{60 - 10} = 2.83$$

The 3rd order Newton is interpolating polynomial becomes:-

$$f_3(x) = 2.83x^3 - 86.24x^2 + 355.75x - 7068.50$$

Then the polynomial function is define by:-

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2) \quad f_3(2016) = 7,818.00$$

$$f_3(x) = 2.83x^3 - 86.24x^2 + 355.75x - 7068.50$$

Eq. (1.21)

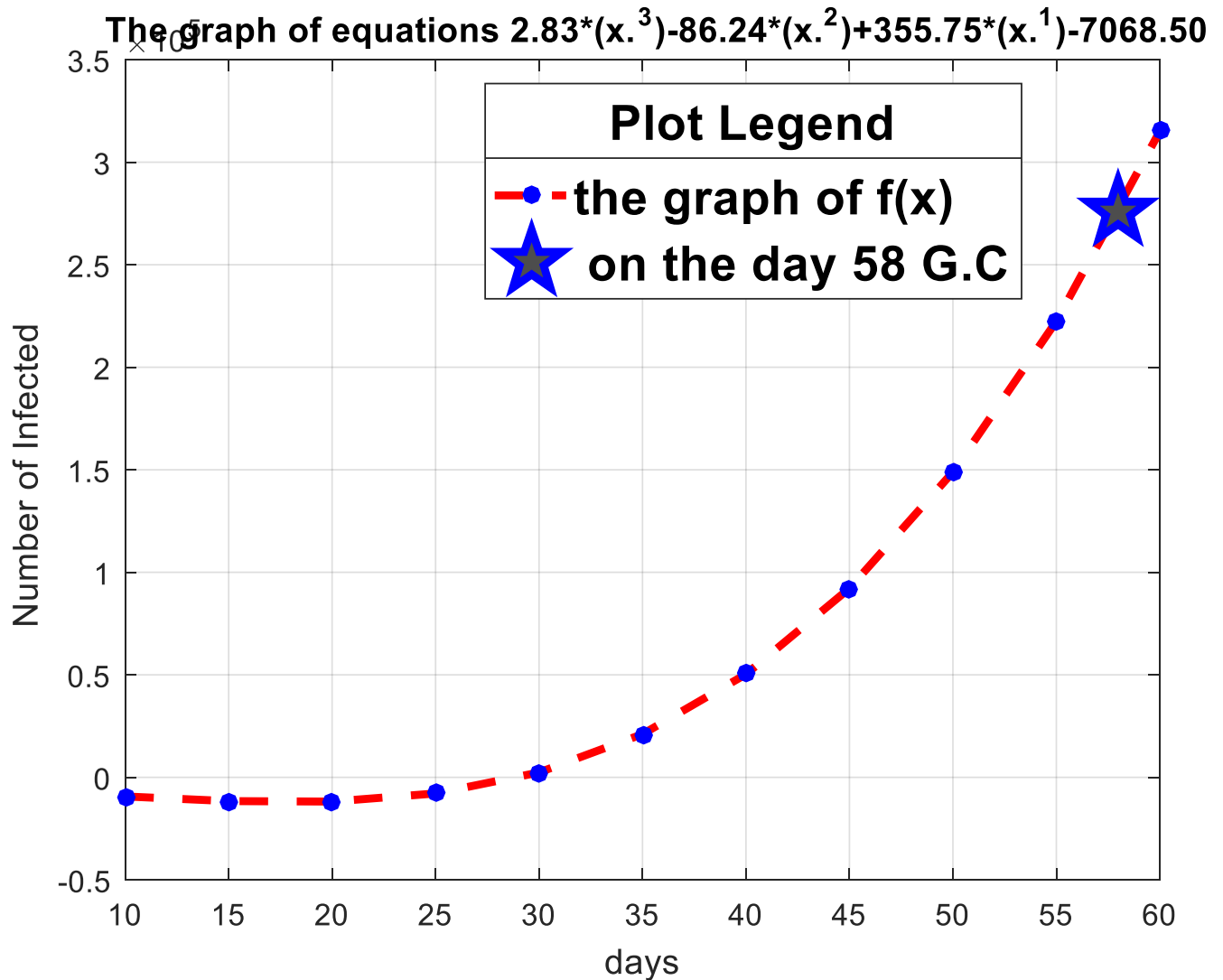


Figure 46 sixty days Interpolation on 58th days on the number of people who are infected.

5.2. Running the SIR model Covid-19 Outbreak in Ethiopia in May 9, 2020

If we now take the example of the Coronavirus (Covid-19) outbreak in Ethiopia May 9, 2020 we can assign the parameters with the following values. The total population of Ethiopia, $N = 114963588$, and according to data from WHO, the number of people infected ($I = 95$) and the number of people dead is 95. Contains the number of people who have established perpetual immunity seeing as R , this includes those who have perished as they have perpetual protection, in addition to those who have recovered with perpetual protection.

Therefore, number of people recovered $R = 95 + (0.3 \times 95) = 123.50$

I will now use this data with the following values to provide the parameters.

$$N = 114963588$$

$$I = 95$$

$$R = 123.5$$

$$\text{Therefore, } S = N - I + R = 114963588 - (123.5 + 95) = 114963559.5$$

The duration of the disease ranges from more than 12 minutes, therefore we could roughly estimate the duration of the disease at the midpoint, i.e., 6 minutes.

$$D = 6$$

$$\gamma = \frac{1}{6} = 0.1667$$

According to WHO, the mortality rate of Corona Virus (Covid-19) is 0.7th and the number of people susceptible is 114963588,

$$\text{Therefore from equation 5, } \beta = \frac{0.7}{114963588} = 6.08 \times 10^{-7}$$

To predict the development of the disease in directive to use the SIR prototypical, it would be helpful if we could resolve the system of ODR. With an explicit formula solution these equations cannot be completely solve.

Therefore , I will use a numerical approach, as follows , For each day, I will calculate the values of $\frac{ds}{dt}$, $\frac{dI}{dt}$ and $\frac{dR}{dt}$ using equations 1, 2 and equations 1,2,3. Then assume that the S value for the following day is the previous S value + $\frac{ds}{dt}$ for that point in time.

I will do this explicitly for the transition from t = 1. The values by equations 1, 2 and 3 from earlier, for the three S, I and R can be considered with the rates of transformation.

$$\frac{ds}{dt}_{t=0} = (-1.63 \times 10^{-7}) \times 95 \times 114963588 = -1780.21$$

$$\frac{ds}{dt}_{t=0} = (1.6 \times 10^{-7}) - (0.1 \times 95) = -95$$

Therefore, at t = 1,

$$S = 114963588 - (-95) = 114963683$$

I will now procedures excel to do this over a two month period, by putting in the formulae in the following technique. I defined γ in as g in cell I1 and β as b in cell J3:

Table 6 data running the SIR model on the initial values figures of the Covid-19 Outbreak in Ethiopia in May 9, 2020

T	S	I	R	ds/dt	dI/dt	dR/dt	S+I+R	gamma	beta
0	114963588	95	123	-40	31	10	114963806	0.1	0
1	114963548	126	133	-53	41	13	114963806	0.1	3.68E-09
2	114963495	166	145	-70	54	17	114963806	0.1	3.68E-09
3	114963424	220	162	-93	71	22	114963806	0.1	3.68E-09
4	114963331	292	184	-123	94	29	114963806	0.1	3.68E-09
5	114963207	386	213	-163	125	39	114963806	0.1	3.68E-09
6	114963044	511	251	-216	165	51	114963806	0.1	3.68E-09
7	114962828	676	303	-286	219	68	114963806	0.1	3.68E-09
8	114962541	895	370	-379	289	89	114963806	0.1	3.68E-09
9	114962162	1184	460	-502	383	118	114963806	0.1	3.68E-09
10	114961661	1567	578	-664	507	157	114963806	0.1	3.68E-09
11	114960997	2074	735	-879	671	207	114963806	0.1	3.68E-09
12	114960118	2745	942	-1163	888	275	114963806	0.1	3.68E-09
13	114958956	3634	1217	-1539	1176	363	114963806	0.1	3.68E-09
14	114957417	4809	1580	-2037	1556	481	114963806	0.1	3.68E-09
15	114955380	6365	2061	-2696	2059	637	114963806	0.1	3.68E-09
16	114952684	8424	2697	-3568	2725	842	114963806	0.1	3.68E-09
17	114949117	11150	3540	-4722	3607	1115	114963806	0.1	3.68E-09
18	114944395	14756	4655	-6249	4773	1476	114963806	0.1	3.68E-09

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19	114938146	19530	6130	-8270	6317	1953	114963806	0.1	3.68E-09
20	114929876	25847	8083	-10944	8360	2585	114963806	0.1	3.68E-09
21	114918931	34206	10668	-14483	11062	3421	114963806	0.1	3.68E-09
22	114904449	45268	14089	-19164	14637	4527	114963806	0.1	3.68E-09
23	114885285	59905	18616	-25355	19365	5990	114963806	0.1	3.68E-09
24	114859930	79270	24606	-33545	25618	7927	114963806	0.1	3.68E-09
25	114826385	104887	32533	-44372	33883	10489	114963806	0.1	3.68E-09
26	114782013	138771	43022	-58684	44806	13877	114963806	0.1	3.68E-09
27	114723330	183577	56899	-77592	59234	18358	114963806	0.1	3.68E-09
28	114645738	242811	75257	-102558	78277	24281	114963806	0.1	3.68E-09
29	114543180	321089	99538	-135500	103391	32109	114963806	0.1	3.68E-09
30	114407680	424479	131647	-178919	136471	42448	114963806	0.1	3.68E-09
31	114228761	560950	174095	-236072	179977	56095	114963806	0.1	3.68E-09
32	113992689	740927	230190	-311169	237077	74093	114963806	0.1	3.68E-09
33	113681520	978004	304282	-409614	311814	97800	114963806	0.1	3.68E-09
34	113271905	1289818	402083	-538264	409282	128982	114963806	0.1	3.68E-09
35	112733642	1699100	531065	-705695	535785	169910	114963806	0.1	3.68E-09
36	112027947	2234884	700975	-922414	698925	223488	114963806	0.1	3.68E-09
37	111105533	2933810	924463	-1200914	907533	293381	114963806	0.1	3.68E-09
38	109904619	3841343	1217844	-1555405	1171271	384134	114963806	0.1	3.68E-09
39	108349214	5012614	1601978	-2000942	1499680	501261	114963806	0.1	3.68E-09
40	106348272	6512294	2103240	-2551578	1900349	651229	114963806	0.1	3.68E-09
41	103796694	8412643	2754469	-3217069	2375805	841264	114963806	0.1	3.68E-09
42	100579624	10788448	3595733	-3997730	2918885	1078845	114963806	0.1	3.68E-09
43	96581895	13707333	4674578	-4877453	3506720	1370733	114963806	0.1	3.68E-09
44	91704441	17214053	6045311	-5815914	4094508	1721405	114963806	0.1	3.68E-09
45	85888528	21308562	7766717	-6742698	4611842	2130856	114963806	0.1	3.68E-09
46	79145829	25920404	9897573	-7558128	4966087	2592040	114963806	0.1	3.68E-09
47	71587701	30886491	12489613	-8146132	5057483	3088649	114963806	0.1	3.68E-09
48	63441570	35943974	15578262	-8401260	4806863	3594397	114963806	0.1	3.68E-09

EPIDEMIOLOGICAL STUDY AND COMMENTS ON TWO HIGHLY CONTAGIOUS DISEASES IN AFRICA

49	55040309	40750837	19172660	-8263458	4188375	4075084	114963806	0.1	3.68E-09
50	46776851	44939211	23247744	-7744633	3250712	4493921	114963806	0.1	3.68E-09
51	39032218	48189924	27741665	-6929851	2110859	4818992	114963806	0.1	3.68E-09
52	32102366	50300783	32560657	-5949168	919090	5030078	114963806	0.1	3.68E-09
53	26153198	51219872	37590735	-4935234	-186753	5121987	114963806	0.1	3.68E-09
54	21217965	51033119	42712723	-3989333	-1113979	5103312	114963806	0.1	3.68E-09
55	17228632	49919140	47816034	-3168563	-1823351	4991914	114963806	0.1	3.68E-09
56	14060069	48095789	52807948	-2491374	-2318205	4809579	114963806	0.1	3.68E-09
57	11568695	45777584	57617527	-1951110	-2626649	4577758	114963806	0.1	3.68E-09
58	9617585	43150935	62195286	-1528976	-2786117	4315094	114963806	0.1	3.68E-09
59	8088609	40364818	66510379	-1202877	-2833605	4036482	114963806	0.1	3.68E-09
60	6885732	37531213	70546861	-952110	-2801011	3753121	114963806	0.1	3.68E-09
61	5933622	34730202	74299982	-759227	-2713793	3473020	114963806	0.1	3.68E-09
62	5174395	32016409	77773002	-610347	-2591294	3201641	114963806	0.1	3.68E-09
63	4564048	29425114	80974643	-494781	-2447731	2942511	114963806	0.1	3.68E-09
64	4069267	26977384	83917155	-404446	-2293292	2697738	114963806	0.1	3.68E-09
65	3664821	24684091	86614893	-333284	-2135125	2468409	114963806	0.1	3.68E-09
66	3331538	22548966	89083302	-276768	-1978129	2254897	114963806	0.1	3.68E-09
67	3054770	20570838	91338199	-231513	-1825571	2057084	114963806	0.1	3.68E-09
68	2823257	18745267	93395283	-194978	-1679548	1874527	114963806	0.1	3.68E-09
69	2628278	17065718	95269809	-165250	-1541322	1706572	114963806	0.1	3.68E-09
70	2463029	15524396	96976381	-140873	-1411566	1552440	114963806	0.1	3.68E-09
71	2322156	14112830	98528821	-120740	-1290543	1411283	114963806	0.1	3.68E-09
72	2201416	12822286	99940104	-103995	-1178234	1282229	114963806	0.1	3.68E-09
73	2097421	11644053	101222332	-89978	-1074428	1164405	114963806	0.1	3.68E-09
74	2007444	10569625	102386738	-78171	-978791	1056962	114963806	0.1	3.68E-09
75	1929272	9590834	103443700	-68170	-890913	959083	114963806	0.1	3.68E-09
76	1861102	8699921	104402783	-59653	-810339	869992	114963806	0.1	3.68E-09
77	1801449	7889581	105272775	-52363	-736596	788958	114963806	0.1	3.68E-09
78	1749087	7152986	106061734	-46094	-669205	715299	114963806	0.1	3.68E-09

EPIDEMIOLOGICAL STUDY AND COMMENTS ON TWO HIGHLY CONTAGIOUS DISEASES IN AFRICA

79	1702993	6483781	106777032	-40680	-607698	648378	114963806	0.1	3.68E-09
80	1662313	5876083	107425410	-35987	-551621	587608	114963806	0.1	3.68E-09
81	1626326	5324462	108013019	-31903	-500543	532446	114963806	0.1	3.68E-09
82	1594423	4823918	108545465	-28337	-454055	482392	114963806	0.1	3.68E-09
83	1566086	4369863	109027857	-25213	-411773	436986	114963806	0.1	3.68E-09
84	1540873	3958090	109464843	-22470	-373339	395809	114963806	0.1	3.68E-09
85	1518403	3584751	109860652	-20054	-338422	358475	114963806	0.1	3.68E-09
86	1498350	3246329	110219127	-17921	-306712	324633	114963806	0.1	3.68E-09
87	1480429	2939617	110543760	-16033	-277928	293962	114963806	0.1	3.68E-09
88	1464396	2661688	110837722	-14360	-251809	266169	114963806	0.1	3.68E-09
89	1450036	2409880	111103890	-12874	-228114	240988	114963806	0.1	3.68E-09
90	1437162	2181766	111344878	-11552	-206625	218177	114963806	0.1	3.68E-09
91	1425610	1975141	111563055	-10374	-187140	197514	114963806	0.1	3.68E-09
92	1415236	1788001	111760569	-9323	-169477	178800	114963806	0.1	3.68E-09
93	1405913	1618524	111939369	-8383	-153469	161852	114963806	0.1	3.68E-09
94	1397530	1465055	112101222	-7543	-138962	146505	114963806	0.1	3.68E-09
95	1389986	1326093	112247727	-6791	-125818	132609	114963806	0.1	3.68E-09
96	1383195	1200274	112380336	-6117	-113911	120027	114963806	0.1	3.68E-09
97	1377079	1086363	112500364	-5512	-103125	108636	114963806	0.1	3.68E-09
98	1371567	983239	112609000	-4968	-93355	98324	114963806	0.1	3.68E-09
99	1366599	889883	112707324	-4480	-84508	88988	114963806	0.1	3.68E-09
100	1362118	805375	112796312	-4042	-76496	80538	114963806	0.1	3.68E-09
101	1358077	728879	112876850	-3647	-69241	72888	114963806	0.1	3.68E-09
102	1354430	659638	112949738	-3292	-62672	65964	114963806	0.1	3.68E-09
103	1351138	596966	113015702	-2972	-56725	59697	114963806	0.1	3.68E-09
104	1348167	540241	113075398	-2683	-51341	54024	114963806	0.1	3.68E-09
105	1345483	488900	113129422	-2424	-46467	48890	114963806	0.1	3.68E-09
106	1343060	442434	113178312	-2189	-42054	44243	114963806	0.1	3.68E-09
107	1340871	400380	113222556	-1978	-38060	40038	114963806	0.1	3.68E-09
108	1338893	362320	113262594	-1787	-34445	36232	114963806	0.1	3.68E-09

109	1337105	327875	113298826	-1615	-31172	32787	114963806	0.1	3.68E-09
110	1335490	296703	113331613	-1460	-28210	29670	114963806	0.1	3.68E-09
111	1334030	268492	113361283	-1320	-25530	26849	114963806	0.1	3.68E-09
112	1332711	242963	113388133	-1193	-23103	24296	114963806	0.1	3.68E-09
113	1331518	219859	113412429	-1079	-20907	21986	114963806	0.1	3.68E-09
114	1330439	198952	113434415	-975	-18920	19895	114963806	0.1	3.68E-09
115	1329464	180032	113454310	-882	-17121	18003	114963806	0.1	3.68E-09
116	1328582	162910	113472313	-797	-15494	16291	114963806	0.1	3.68E-09
117	1327785	147417	113488604	-721	-14021	14742	114963806	0.1	3.68E-09
118	1327064	133396	113503346	-652	-12687	13340	114963806	0.1	3.68E-09
119	1326412	120709	113516686	-590	-11481	12071	114963806	0.1	3.68E-09
120	1325822	109228	113528756	-534	-10389	10923	114963806	0.1	3.68E-09

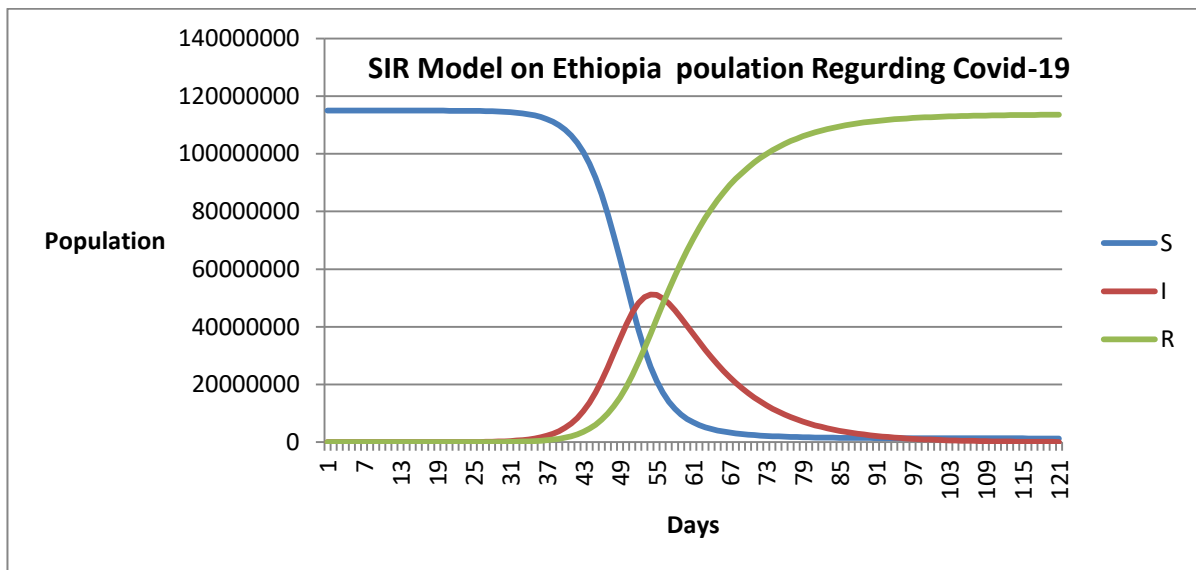


Figure 47 SIR Model on Ethiopia population regarding Covid-19

Table 7 Tabular data for sixty days and the given tabular data 1,2, 3, 4, 5, and 6

No.	Days	Confirmed cases
1.	May 10,2020	239
2.	May 11,2020	250
3.	May 12,2020	261
4.	May 13 at 1:00	263
5.	May 15,2020	287

5.2.1 Polynomial interpolation

A polynomial of order n that passes through $n + 1$ points and using Equation (1), we can solve the given question of order three polynomials the points are:-

$$x_0 = 1, \quad x_1 = 2, \quad x_2 = 4, \quad x_3 = 5$$

$$f(x_0) = 239, \quad f(x_1) = 250, \quad f(x_2) = 263, \quad f(x_3) = 287$$

Then, The Newton’s interpolating polynomial become:-

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2)$$

$$b_0 = f(x_0) = 239$$

$$b_1 = f[x_1, x_0] = \frac{f(x_1) - f(x_0)}{x_1 - x_0} = \frac{250 - 239}{2 - 1} = 11$$

$$b_2 = f[x_2, x_1, x_0] = \frac{\frac{f(x_2) - f(x_1)}{x_2 - x_1} - \frac{f(x_1) - f(x_0)}{x_1 - x_0}}{x_2 - x_0} = \frac{\left(\frac{263 - 250}{4 - 2}\right) - \left(\frac{250 - 239}{2 - 1}\right)}{4 - 1} = -1.5$$

$$b_3 = f[x_3, x_2, x_1, x_0] = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0}$$

$$f[x_3, x_2, x_1] = \frac{\frac{f(x_3) - f(x_2)}{x_3 - x_2} - \frac{f(x_2) - f(x_1)}{x_2 - x_1}}{x_3 - x_1} = \frac{\left(\frac{287 - 263}{5 - 4}\right) - \left(\frac{263 - 250}{4 - 2}\right)}{5 - 2} = 5.83$$

$$b_3 = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0} = \frac{5.83 - (-1.5)}{5 - 1} = 1.83$$

5.2.2 Third Order Finite Divided Differences for a given Function f(x)

The third order Newton is interpolating polynomial becomes

$$f_3(x) = 239 + 11(x-1) - 1(x-1)(x-2) + 1.83(x-1)(x-2)(x-5)$$

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2)$$

Then the polynomial function is defined by:-

$$f_3(x) = 1.8x^3 - 15.4x^2 + 31.4x - 248$$

Eq. (1.23)

A polynomial of order involves finding n that passes through the n+1 points and using Equation (1), we can solve the given question of order three polynomials the points are:-

$$x_0 = 10, \quad x_1 = 25, \quad x_2 = 45, \quad x_3 = 60$$

$$f(x_0) = 1378, \quad f(x_1) = 2046, \quad f(x_2) = 3696, \quad f(x_3) = 4262$$

$$x_0 = 1, \quad x_1 = 2, \quad x_2 = 4, \quad x_3 = 5$$

$$f(x_0) = 239, \quad f(x_1) = 250, \quad f(x_2) = 263, \quad f(x_3) = 287$$

Then, The Newton's interpolating polynomial become:-

$$f_3(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + b_3(x - x_0)(x - x_1)(x - x_2)$$

$$f_3(x) = 1.8x^3 - 15.4x^2 + 31.4x - 248$$

$$b_1 = f[x_1, x_0] = \frac{f(x_1) - f(x_0)}{x_1 - x_0} = \frac{250 - 239}{2 - 1} = 11$$

$$b_2 = f[x_2, x_1, x_0] = \frac{\frac{f(x_2) - f(x_1)}{x_2 - x_1} - \frac{f(x_1) - f(x_0)}{x_1 - x_0}}{x_2 - x_0} = \frac{\left(\frac{239 - 250}{4 - 2}\right) - \left(\frac{250 - 239}{2 - 1}\right)}{4 - 1} = -22$$

$$b_3 = f[x_3, x_2, x_1, x_0] = \frac{f[x_3, x_2, x_1] - f[x_2, x_1, x_0]}{x_3 - x_0}$$

$$f[x_3, x_2, x_1] = \frac{\frac{f(x_3) - f(x_2)}{x_3 - x_2} - \frac{f(x_2) - f(x_1)}{x_2 - x_1}}{x_3 - x_1} = \frac{\left(\frac{287 - 263}{5 - 4}\right) - \left(\frac{263 - 250}{4 - 2}\right)}{5 - 2} = 5.83$$

$$f_3(x) = 1.8x^3 - 15.4x^2 + 31.4x - 248$$

The third order Newton is interpolating polynomial become:-

$$f_3(x) = 2.83x^3 - 86.24x^2 + 355.75x - 7068.50$$

Then the polynomial function is defined by:-

$$f_3(x) = 1.8x^3 - 15.4x^2 + 31.4x - 248$$

Eq. (1.24)

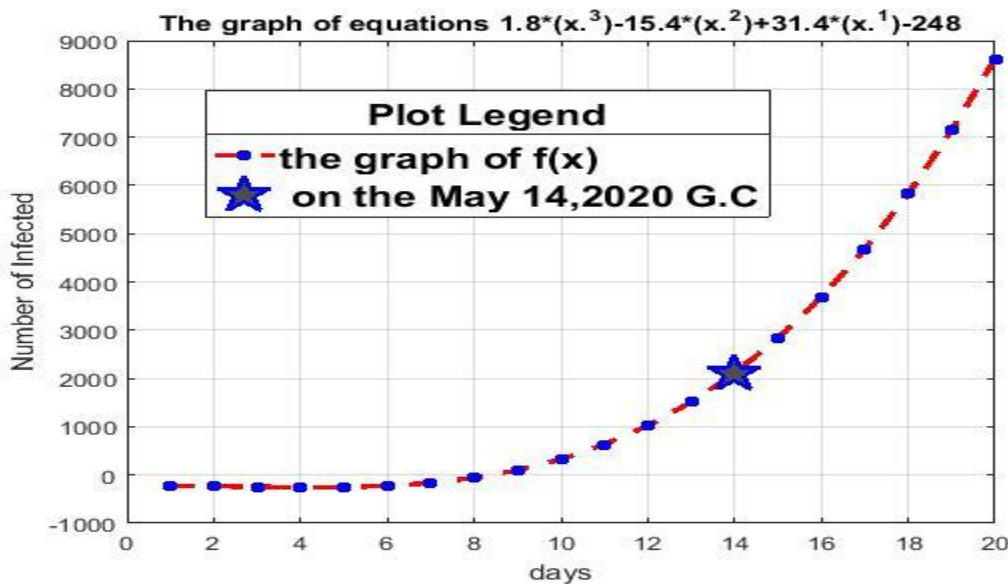


Figure 48 Interpolation on between days

Chapter 6 The Impact of social Media

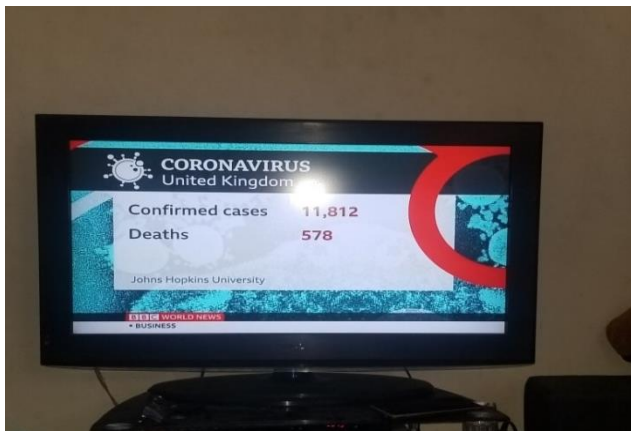
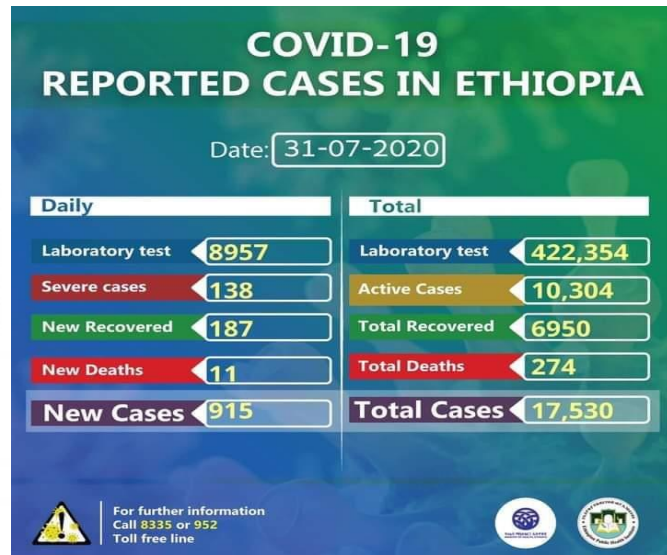


Figure 49 the Impact of social media in Ethiopia

Due to the media report it is really impacted the whole country to prevent and slow down the spread of the disease. The ministry of health reporting daily to each one of us through social media about coronavirus (Covid-19) excelling. due to that most of the time the ministry of health kept on telling us or warning us to wear mask, social distancing, wash your hand and sanitize and soon. We are getting data applying out of carless some did not reach to applying but the disease is outshining. The interventions of social Media are impacting by informing the spread of the virus.

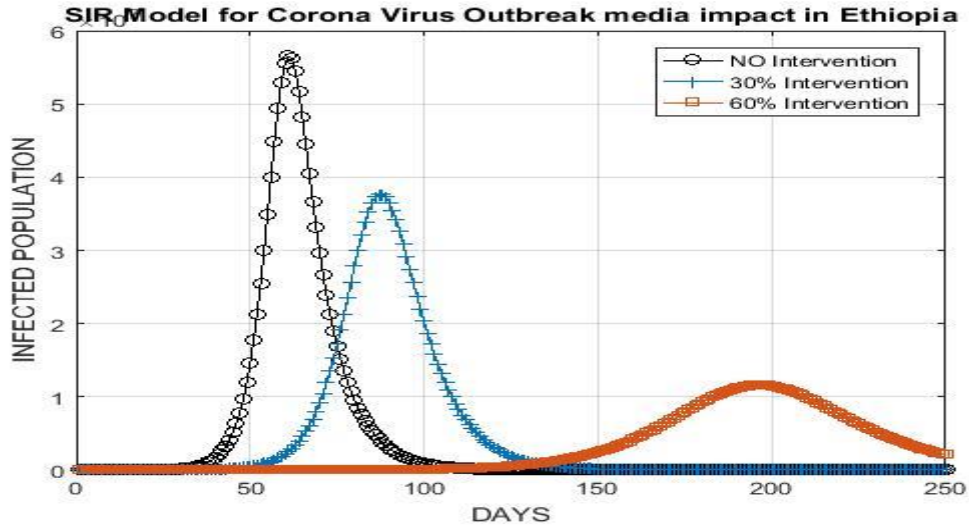


Figure 50 The Impact social media in Ethiopia

$s(1)= 114963588$; $in(1)= 294$; $r(1)= 128$; $G=0.1$; $B=0.42/114963588$; $dt=1$; $FF = [0 \ 0.3 \ 0.6]$; % given NO Intervention', '30% Intervention', '60% Intervention the blue color we see 30% intervention, yellow color we see sixty percent intervention and the black color we see no intervention. In general we see when there is intervention increases 1 percent we see the mass media impact the infected people decreases.

The Impact of intervention

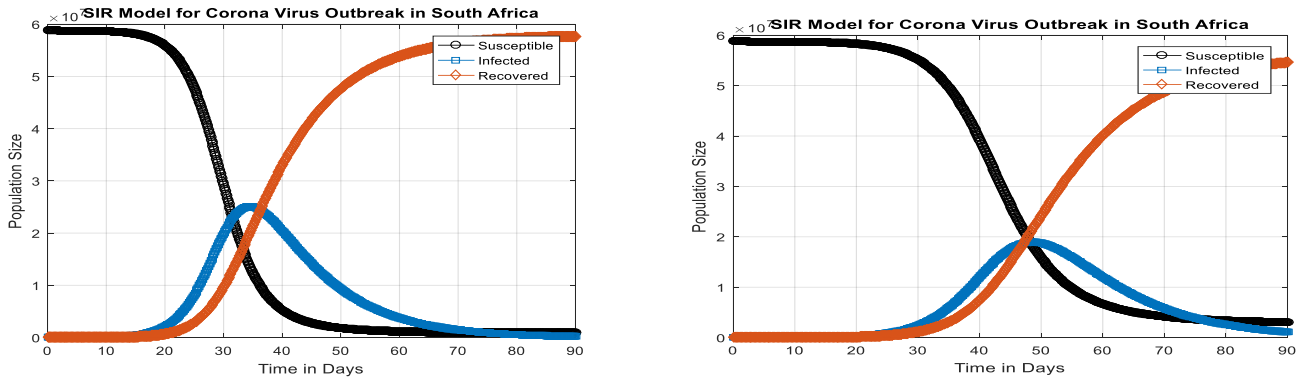


Figure 51 The impact of intervention

A. Without Contact reduction from media

B. with contact reduction of media.

Figure 54 A and B compare media Intervention of 25% with a case of no media intervention. As we can see clearly the media intervention serves two major purposes. First it can be seen from figure 54 A and B the infection curve start is delayed which helps governments and policy makers to buy to implement other memories. It may also help us buy time to prepare vaccination if possible. The second purpose is that it can be seen from figure the maximum infected are reduced.

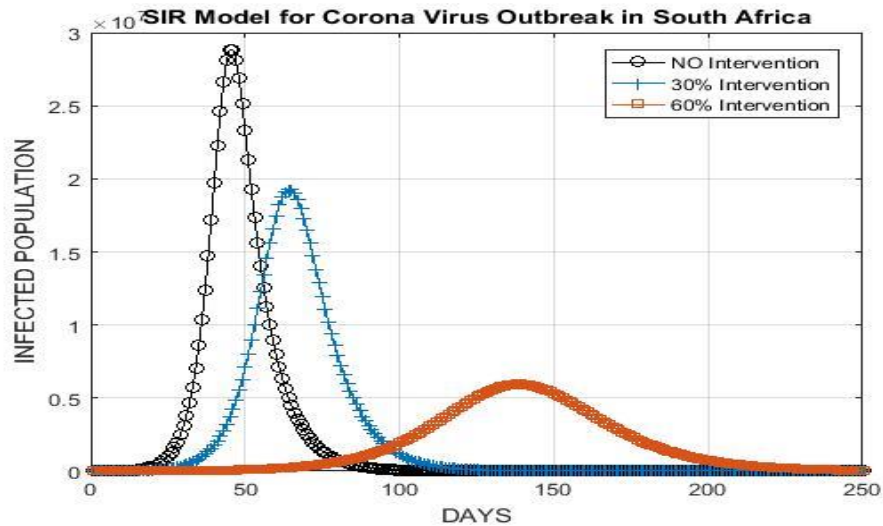


Figure 52 South Africa social media assumption data.

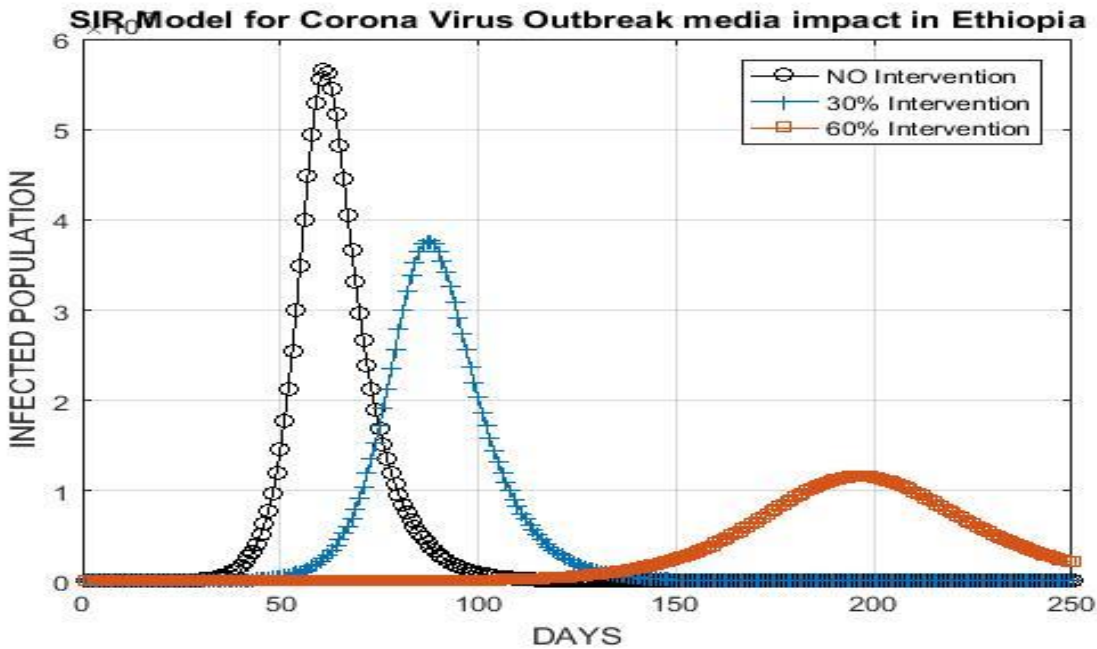


Figure 53 Ethiopian social media assumption data

When there is no intervention to the people as we can see from the graph the plot is high compare to others, when we see the 30% intervention the susceptible people decrease as we can see the blue color declining compare to no intervention whereas the 60% intervention more less than the 30% and with no intervention.

6.1 Modeling the Spread of COVID-19

In the last several months, the rapid spread of COVID-19— originally the disease caused by the respiratory condition coronavirus has turned our daily lives upside down. The number of confirmed cases was well over one million as of early April, with the number of total infections certainly much higher. Exponential growth this is because the virus’s spread is a classic example of, in which the upsurge of some amount in this case, the infected people is comparative to its current size. Newly-infected person becomes another source of infection because each Infectious virus grows exponentially [15].

The SIR model one of the simplest epidemiological models and it divides the population into three groups:

- Susceptible persons
- Infectious persons
- Recovered persons

The model takes the form that describes three differential equation ODE (ordinary differential equation) the rates at which being's transition between these groups:

$$\frac{dS}{dt} = \beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

The virus spreads each time an infectious person encounters a susceptible person, meanwhile, (gamma) is the average infectious period. Thus, if a single individual is initially infectious, he/she will pass the disease to (R₀ = beta/gamma) other people on average. R₀ is called the basic reproduction number and is a property of both the disease and the behavior of the population in which it broadcasts. The respective fractions of the population in the susceptible, infectious, and recovered groups are S (t), I (t), and (R (t)). We assume that people randomly come into contact with each other at a rate of (beta) encounters per person in a day.

Modeling COVID-19's the natural consequence of rapid spread within a completely susceptible population is a pandemic that peaks during the summer and infects the great majority of humankind displays the results of spread on a global scale with these parameters. Although most cases of COVID-19 are slight or asymptomatic, it is clear that this scenario would completely overwhelm the healthcare systems in every country for at least several weeks during the peak of the crisis.

6.2 Equilibrium

since all terms on the right-hand side of the system are proportional to (I) The SIR model is at equilibrium if and only if (I=0), a small local outbreak will not spread If this equilibrium is stable, But if it is unstable, any small outbreak will become a global epidemic. Eigenvalue analysis confirms what we have already observed:

6.3 Non Pharmaceutical Intervention

There are two types of intervention

1. Wearing mask
2. .Social distancing

The contact rate beta is constant in time the basic SIR model assumes but as with COVID-19, a threatened population may change its manners in an exertion to decrease the rate of interaction and slow or stop a

disease’s blowout. This is the aim of the current extensive and work ends, stay-at-home orders, and other preventive public hostility procedures. We can include the medical literature refers to such phenomena as non-pharmaceutical interventions in the SIR model as follows:

$$\frac{dS}{dt} = (1 - f)\beta SI$$

$$\frac{dI}{dt} = (1 - f)\beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

Real-world interventions lie somewhere between these two extremes we have (q=0), in the absence of intervention, In contrast, putting each person in complete isolation yields (q=1). .

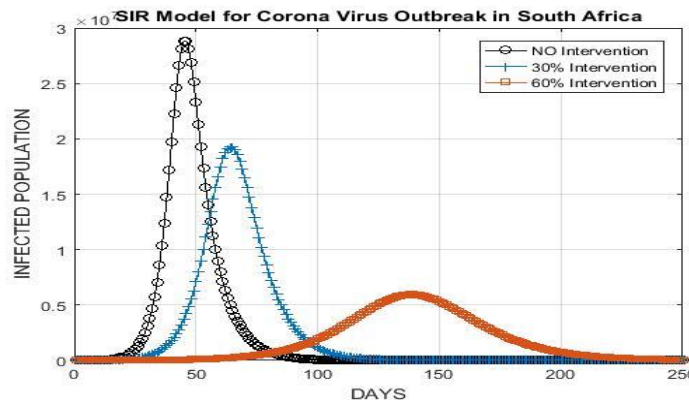


Figure 54 flattening the curve through contact reduction.

One consequence of exponential growth is that interventions are most effective when they are imposed before a pandemic becomes widespread. Spanish flu pandemic a study in 1918 found that reduced peak rates of infection strongly correlated with how early a community imposed intervention measures.

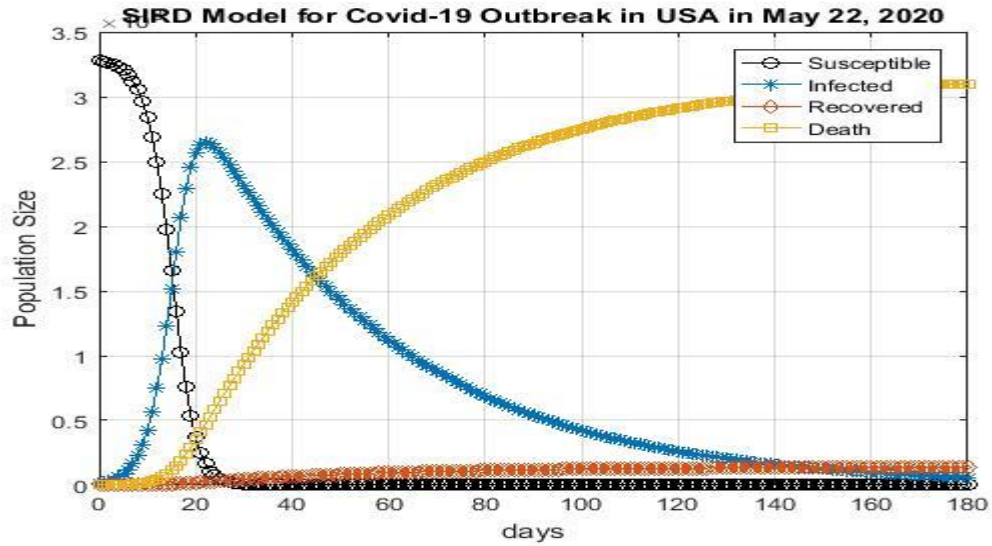


Figure 55 Covid-19 plot USA Data May 22

$S(1) = 328000000$; $I_n(1) = 1657441$; $R(1) = 462297$; $D(1) = 98034$; $\gamma = 0.001$; $\beta = 0.42 / S(1)$; $\mu = 0.2$; $\alpha = 0.023$

; the population of USA is 328.2 million Susceptible the number of infection increasing daily but in the case of the above graph the blue color clearly shows the rate Goth up and slowly decreasing as the recovering people increases. And the death rate shows increasing daily.

6.4 Equilibrium Points

For an SIR system with a constant population size Linearization approximation is a standard phase plane technique used to analyze system dynamics. Using the assumption of no recovered infected population we have the following system of two independent nonlinear differential equations.

$$\frac{dS}{dt} = \alpha - \beta SI - \delta S$$

$$\frac{dI}{dt} = \beta SI - (\gamma + \delta)I$$

Eq. (1.25)

For the equilibrium points we then solve the reduced system of nonlinear equation. Thus the

$$\alpha - \beta SI - \delta I = 0$$

$$\beta SI - (\gamma + \delta)I = 0$$

Solving the above equations simultaneously and let $I=0$, we have

$$\alpha - \beta S(0) - \delta S = 0$$

$$\alpha - \delta S = 0$$

Eq.(1.26)

Solving the above equation from the value of S , we have $S = \frac{\alpha N}{\delta}$ but let $\alpha = \delta$, implies $S=N$. Hence the first equilibrium point is $(S^*, I^*) = (N, 0)$, this is called the disease free equilibrium.

Let $I \neq 0, S = \frac{\gamma + \delta}{\beta}$ substituting the value of S into the equation we have $I \neq 0, S = \frac{\gamma + \delta}{\beta}$

$$\alpha - \beta \left(\frac{\gamma + \delta}{\beta} \right) I - \delta \left(\frac{\gamma + \delta}{\beta} \right) = 0$$

Eq. (1.27)

From which we get

$$I - \delta \frac{\alpha\beta - \delta(\gamma + \delta)}{\beta(\gamma + \delta)} = 0.$$

Eq. (1.28)

Thus the equilibrium points is

$$(S^*, I^*) = \left(\frac{\gamma + \delta}{\beta}, \frac{\alpha\beta - \delta(\gamma + \delta)}{\beta(\gamma + \delta)} \right) = 0$$

Eq. (1.29)

6.5 Stability of the model

In this section, we consider some important methods of establishing stability of equilibrium points of non-linear differential equations. We use the Jacobean matrix to determine the eigenvalues and eigenvectors which in turn determines our stability of equilibrium point.

Using equations (1.40 and 1.41) we can construct the following Jacobian - matrix.

$$J = \begin{pmatrix} -\beta - \delta & -\beta S \\ \beta & \beta S - \gamma - \delta \end{pmatrix} \quad \text{Eq. (1.30)}$$

Consider the linear system $x' = Jx$, where $\det(J)$ is not equal to. Let the eigenvalues of J be λ_1, λ_2 the following is true of the critical point $(S^*, I^*) = (N, 0)$

- The real critical point is stable if of λ_1, λ_2 are both negative.
- The critical point any solution is an ellipse centered about if the real parts of λ_1, λ_2 is both zero.
- The real part of either λ_1 or λ_2 is positive the critical point is unstable.

6.6 Disease Free Equilibrium

In order to determine the stability of the model at this point, we evaluate the Jacobean matrix at this equilibrium point and find the eigenvalues corresponding to this point at the initial state of the disease we have only the susceptible present from earlier calculations the disease free equilibrium is $(S^*, I^*) = (N, 0)$. In equation at the disease free equilibrium point Evaluating the Jacobean, we have

$$\det(A - \lambda I) = \det \left[\begin{pmatrix} -\delta & -\beta \\ 0 & \beta - \gamma - \delta \end{pmatrix} - \lambda \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \right] \quad \text{Eq. (1.31)}$$

We find the characteristic equation which is given by $\det(A - \lambda I) = 0$ where λ is the eigenvalues and A is an $n \times n$ matrix. Here we replace the $n \times n$ matrix (A) by the Jacobian matrix (J). Thus

$$\det(A - \lambda I) = \det \left[\begin{pmatrix} -\delta & -\beta \\ 0 & \beta - \gamma - \delta \end{pmatrix} - \lambda \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \right] \quad \text{Eq. (1.32)}$$

$$= (-\delta - \lambda)(\beta N - \gamma - \delta - \lambda) - (0)$$

Because $\det(A - \lambda I) = 0$, implies

$$= (-\delta - \lambda)(\beta N - \gamma - \delta - \lambda) - (\beta)(0) = 0$$

Therefore $\lambda_1 = -\delta$ or $\lambda_2 = \beta - \gamma - \delta$, the eigenvalues corresponding to the disease free equilibrium

$$(S^*, I^*) = (N, 0) \text{ are } \lambda_1 = \beta - \gamma - \delta$$

6.7 Endemic equilibrium

The disease cannot be totally eradicated but remains in the population for the disease to persist in the population the endemic equilibrium state is the state where. SIR epidemic model is defined the basic generative number R_0 of a discrete and the dynamical manners of the model are considered. It is verified that the disease free equilibrium is globally asymptotically stable if $R_0 < 1$, and the persistence of the model is obtained when $R_0 > 1$

The endemic equilibrium sufficient conditions the main attention is paid to the global stability of for the global stability of the endemic equilibrium are established by using the comparison principle. Mathematical models have played a important role in relating the dynamical evolution of infectious virus. SIR model is one of the standard epidemic models with section building, suitable for the transmission of infectious virus that discusses long-lasting protection such as chicken pox, SARS and Covid-19. The population of epidemiological groups divided into three groups the susceptible, the infective, and the removed recovered.

At the point in time where all the compartments of the population coexist is called the endemic period. The presence of an infectious person is a problem in the epidemiology of infectious diseases. In this section we consider the situation whereby there id coexistence between the two main categories (i.e. the susceptible and the infectious). This is seen in the endemic equilibrium point in equation below.

$$(s^*, i^*) = \left[\frac{\gamma + \delta}{\beta}, \frac{\alpha\beta - \delta(\gamma + \delta)}{\beta(\gamma + \delta)} \right].$$

This corresponds to the endemic state i.e. In order to determine the stability of this point, we restore to the same approach used in determining the stability of the disease free equilibrium. We evaluate the community (Jacobean) matrix at the endemic point.

$$J(S, I) = \begin{bmatrix} -\beta \left[\frac{\alpha\beta - \delta(\gamma + \delta)}{\beta(\gamma + \delta)} \right] - \delta & -\beta \left(\frac{\gamma + \delta}{\beta} \right) \\ \beta \left[\frac{\alpha\beta - \delta(\gamma + \delta)}{\beta(\gamma + \delta)} \right] & -\beta \left(\frac{\gamma + \delta}{\beta} \right) - (\gamma + \delta) \end{bmatrix}. \quad \text{Eq. (1.33)}$$

$$J(S, I) = \begin{pmatrix} \frac{-\alpha\beta}{\gamma + \delta} & -(\gamma + \delta) \\ \left(\frac{\alpha\beta - \delta(\gamma + \delta)}{\gamma + \delta} \right) & 0 \end{pmatrix} \quad \text{Eq. (1.34)}$$

We then find the characteristic equation which is given by $\det(A - I\lambda) = 0$ where λ is the eigenvalues and A is an n X n matrix. The n X n matrix (A) Jacobian matrix (J).

Thus

$$\det(A - I\lambda) = \det \left\{ \begin{pmatrix} \frac{-\alpha\beta}{\gamma + \delta} & -(\gamma + \delta) \\ \left(\frac{\alpha\beta - \delta(\gamma + \delta)}{\gamma + \delta} \right) & 0 \end{pmatrix} - \lambda \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \right\} \quad \text{Eq. (1.35)}$$

$$= \det \left\{ \begin{pmatrix} \frac{-\alpha\beta}{\gamma + \delta} - \lambda & -(\gamma + \delta) \\ \left(\frac{\alpha\beta - \delta(\gamma + \delta)}{\gamma + \delta} \right) & -\lambda \end{pmatrix} \right\} \quad \text{Eq. (1.36)}$$

$$= \left(\left(\frac{-\alpha\beta}{\gamma+\delta} - \lambda \right) (-\lambda) + (\gamma+\delta) \left(\frac{\alpha\beta - \delta(\gamma+\delta)}{\gamma+\delta} \right) \right) \quad \text{Eq. (1.37)}$$

Because $\det(A - I\lambda) = 0$, implies

$$\left(\frac{-\alpha\beta}{\gamma+\delta} - \lambda \right) (-\lambda) + (\gamma+\delta) \left(\frac{\alpha\beta - \delta(\gamma+\delta)}{\gamma+\delta} \right) = 0 \quad \text{Eq. (1.38)}$$

$$(\gamma+\delta)\lambda^2 + \alpha\beta\lambda + (\gamma+\delta)(\alpha\beta - \delta(\gamma+\delta)) = 0 \quad \text{Eq. (1.39)}$$

$$\lambda_{1,2} = \frac{-\alpha\beta \pm \sqrt{(\alpha\beta)^2 - 4(\gamma+\delta)^2(\alpha\beta - \delta(\gamma+\delta))}}{2(\gamma+\delta)} \quad \text{Eq. (1.40)}$$

The endemic equilibrium to be this gives the eigenvalues of

$$\lambda_{1,2} = \frac{-\frac{\alpha\beta}{(\gamma+\delta)} \pm \sqrt{\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta))}}{2}$$

$$\lambda_1 = \frac{-\frac{\alpha\beta}{(\gamma+\delta)} + \sqrt{\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta))}}{2} \quad \text{OR} \quad \lambda_{1,2} = \frac{-\frac{\alpha\beta}{(\gamma+\delta)} - \sqrt{\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta))}}{2}$$

Depends on the values the stability of the endemic equilibrium of α, β, δ and γ

If $\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta)) = 0$ then the eigenvalues are real and equal. The point is a nodal sink and is stable.

$$\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta)) > 0$$

case1: $\sqrt{\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta))} > \left(\frac{\alpha\beta}{(\gamma+\delta)}\right)$, the real part of eigenvalues are opposite in sign and the critical point I unusable.

case1: $\sqrt{\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta))} < \left(\frac{\alpha\beta}{(\gamma+\delta)}\right)$, the real part of eigenvalues are both negative and the critical point is stable.

$\left(\frac{\alpha\beta}{(\gamma+\delta)}\right)^2 - 4(\alpha\beta - \delta(\gamma+\delta)) < 0$, then eigenvalues are complex conjugates with nonzero real and imaginary parts. The critical point is a spiral sink and is stable because the real parts are both negative.

Due to herd immunity can be applicable to the contagious not infectious disease. The other way is vaccine, Herd immunity very much applicable. This vaccine to function by giving vaccination also the person can protect and to slow the virus to spread so in that case we call it herd immunity took place. If a adequately high amount of individuals a transmissible disease within a people that results the resistances to the spread of are resistant to the disease, especially through vaccination. Herd immunity varies by disease the level of vaccination needed to achieve Translate herd immunity.

Herd Immunity

Herd group protection Herd immunity is also called community immunity. In relation to the outbreak Herd immunity happens when so many people from spreading you've probably heard the term "herd immunity" used.

Herd immunity can happen in two ways:

1. An immune response to it many people contract the disease and in time build up (natural immunity).
2. The disease to achieve immunity many people are vaccinated.

Matlab Apps SIR Model plot on East Africa

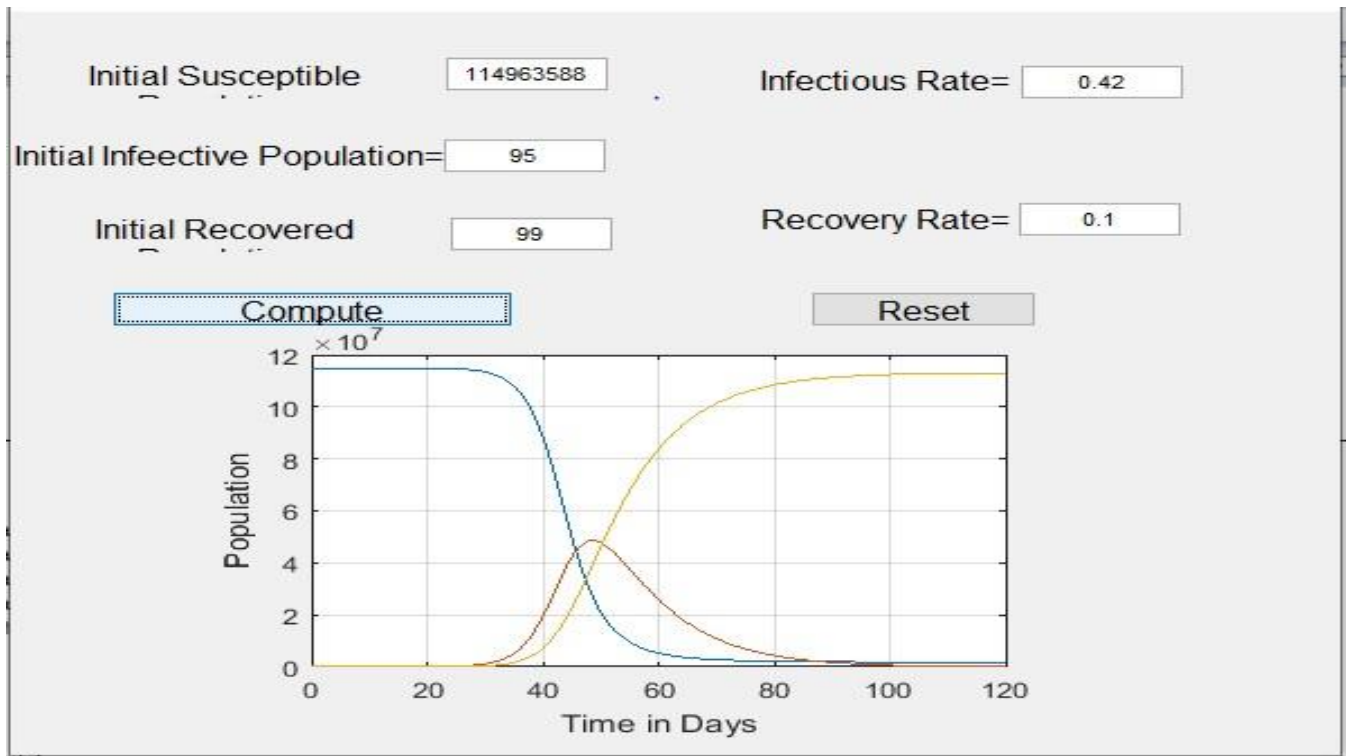


Figure 56 plot of Ethiopia Covid-19 Data

apps as an application which help us to fasten the operation how the virus characterize or behaves in terms of susceptible, Infected and recover with the given infectious Rate and recovery rate. Once you have the data which I mention earlier on different compartments it will automatically plot for us within micro second. This is to me is a good indication for the rest of compartments like SIRD, SIRQD etc.

Just to illustrate Matlab app to indicates about Ethiopia covid-19 in the month of May 9, 2020 which was taken from the above data which I collected for the matlab program. The blue color obviously the susceptible population of Ethiopia and middle color which is the brown color infected and the last one is recovered.

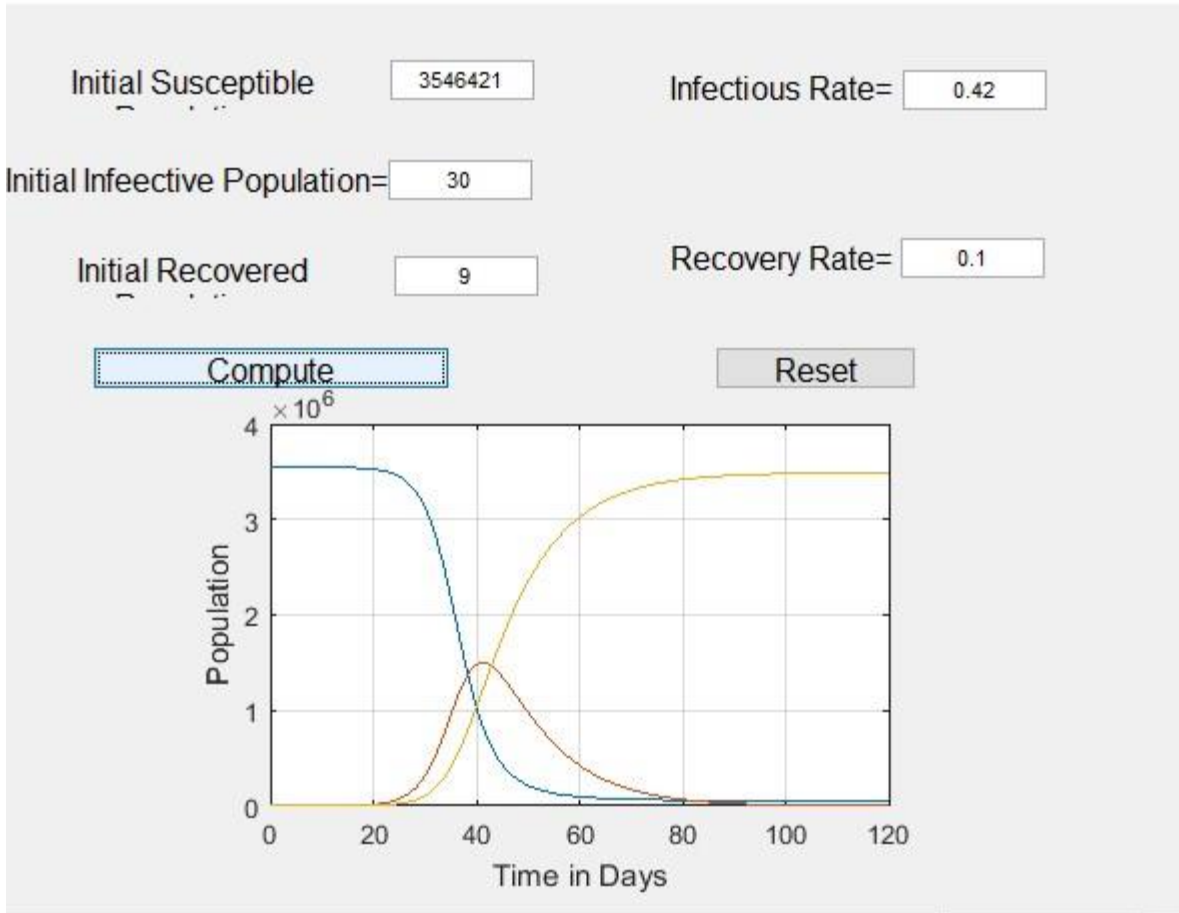


Figure 57 Simple SIR Model Matlab Apps plot on the Data of Eretria

Just to illustrate Mat lab app show and illustrate about Eretria covid-19 in the month of May 9, 2020 which was taken from the above data which I collected for the matlab app. The blue color obviously the susceptible population of Eretria and middle color which is the brown color infected and the last one is recovered.

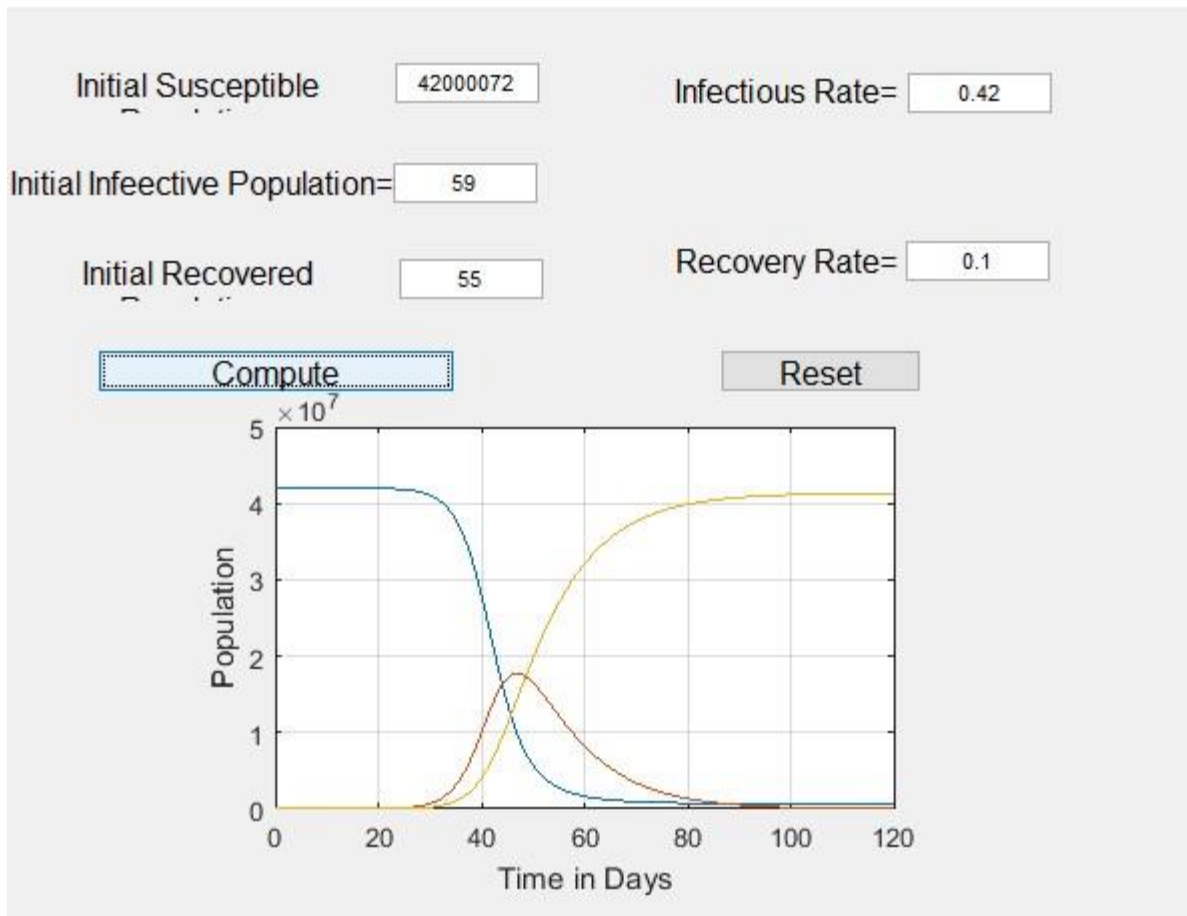


Figure 58 Simple SIR Model Matlab Apps plot on the Data of Uganda.

Just to illustrate Matlab app. Application indicates about Uganda covid-19 in the month of May 9, 2020 which was taken from the above data which I collected for the matlab program. The blue color obviously the susceptible population of Uganda and middle color which is the brown color infected and the last one is recovered.

Chapter 7 Conclusion

By using an SIR model, the efficiency of the available health care systems I was able to see the importance of modeling data, especially in the field of medical and this is because, in order to cope up with the rapid changes in the medical. Impacts of herd immunity on an outbreak as well the application of mathematical models on diseases can be extended to include the effects of vaccination. This can help to determine factors which can help reduce the mortality rate. One of these methods includes mathematical modeling which is becoming increasingly important in helping identify the future of certain diseases.

Through completing this exploration, I am able to see the impact of mathematical modeling and the influences it has in helping scientists to epidemics and Pandemic. The SIR, SIRV, SIQR, SIQVR, model which I used to show the general trend of the pandemic and endemic from doing my exploration, I gained knowledge in way to illustrate the appearance of the spread of virus in order to inform health care in sincere of the necessary protections that must be in place, Nonetheless, similar to most models, the SIR, SIQR, SIRVD, is also subject to limitations as often a model is a simplified representation of the real situation and often this can lead to over simplification, creating conflicts between simplicity and complexity models often attempt to mimic a real life situation through, the aim of modeling is to clarify certain concepts, but introducing many variables and can lead to further confusion.

APPENDIX

Euler’s Method is a numerical approach method to approximating the particular solution of the differential equation that passes through the point. (x_0, y_0) from this we know that the slope passes through

$$y' = F(x, y)$$

We know that Euler’s Method of $\left(\frac{dy}{dt}\right) = y - x; y(0) = 2$ this is the first order method.

$$h = 0.1 \text{ Analytic solution } y(x) = e^x + x + 1, h = 0.1$$

Algorithm of Euler’s method

Step1:- set the given initial condition for (x_0, y_0)

Step2:- request and get input values for h and for n

Step3:- calculate the derivative of y(t) at t = to

Step4:- calculate an approximate value for $y^*(to+h)$

$$y(i+1) = y(i) + h * f(t(i), y(i))$$

Step5:- calculate for the next step size

$$t(i+1) = t(i) + h$$

Step6:- Repeat steps 3 through 5 until the solution is finished.

Use Runge-Kutta 4th order method to solve the given problem $\left(\frac{dy}{dt}\right) = y - x; y(0) = 2$ establish a solution procedure by using numerical Technique and solve up to two steps by hand. Then write a compact computer program

Given equation $\left(\frac{dy}{dt}\right) = y - x; y(0) = 2$ and $h = 0.1$ Analytic solution $y(x) = e^x + x + 1, h = 0.1$

References

- [1] <https://www.cdc.gov/vhf/ebola/about.html> Content source: Centers for Disease Control and Prevention: November 5, 2019
- [2] <https://www.who.int/features/ebola/storymap/en/> © Copyright World Health Organization (WHO), 2020.
- [3] <https://www.livescience.com/48170-ebola-outbreak-in-1976-revisited.html> By Bahar Gholipour October 6, 2014.
- [4] <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5050466/> J Infect Dis. 2016 Oct 15; 214 Suppl 3: S93–S101. Published online 2016 Oct 4. doi: 10.1093/infdis/jiw207.
- [5] <https://web.stanford.edu/group/virus/filo/eboz.html> International Commission. "Ebola haemorrhagic fever in Zaire, 1976." Bulletin of the World Health Organization, 56 (2):271-293 (1978).
- [6] https://www.who.int/health-topics/coronavirus#tab=tab_1 © World Health Organization 2020. Some rights reserved. This work is available under the CC BY-NC-SA 3.0 IGO licence. WHO reference number: WHO/2019nCoV/Adjusting_PH_measures/2020.2
- [7] <https://www.who.int/news-room/fact-sheets/detail/ebola-virus-disease> ,10 February 2020
- [8] <https://www.ncbi.nlm.nih.gov/books/NBK401927/> Copyright 2016 by the National Academy of Sciences BookshelfID:NBK401927.
- [9] <https://www.cdc.gov/vhf/ebola/history/distribution-map.html> Content source: Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID), Division of High Consequence Pathogens and Pathology (DHCPP), Viral Special Pathogens Branch (VSPB).
- [10] <http://www.cdc.gov/ebola/resources/virus-ecology.html>, (Page last reviewed August 1, 2014).
- [11] <https://www.who.int/csr/disease/ebola/ebola-6-months/guinea/en/>
- [12] <https://www.cebm.net/covid-19/coronaviruses-a-general-introduction/> March 25, 2020 | Jeffrey K Aronson
Centre for Evidence-Based Medicine, Nuffield Department of Primary Care Health Sciences University of Oxford. March 2020
- [13] <https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/distribution-map.html> Page last reviewed: March 8, 2019 Content source: Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID), Division of High-Consequence Pathogens and Pathology (DHCPP), Viral Special Pathogens Branch.

[14] <https://www.hindawi.com/journals/ddns/2015/842792/> Copyright © 2015 Amira Rachah and Delfim F. M. Torres.

[15] “Random House Webster’s College Dictionary” P416 second revised and updated Random house edition April 2000.

[16] <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3680036/> Published online 2013 Jun 6.
doi: 10.1371/journal.ppat.1003277.

[17] <https://coronavirus.jhu.edu/map.html>. Cited on 18.

[18] <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7181939/>Articles from Emerging Infectious Diseases are provided here courtesy of Centers for Disease Control and Prevention.

[19] Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med* 2020. doi: 10.1056/NEJMoa2001316.